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(54) **SECONDARY HOLE TRANSPORTING LAYER WITH DIARYLAMINO-PHENYL-CARBAZOLE COMPOUNDS**

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C07D 405/04	(2006.01)
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C07D 209/86	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 51/0072*** (2013.01); ***C07D 409/14*** (2013.01); ***C07D 405/04*** (2013.01); ***C07D 409/04*** (2013.01); ***C07D 209/86*** (2013.01); *H01L 51/5064* (2013.01); *H01L 51/0054* (2013.01); *H01L 51/006* (2013.01); *H01L 51/0061* (2013.01); *H01L 51/0074* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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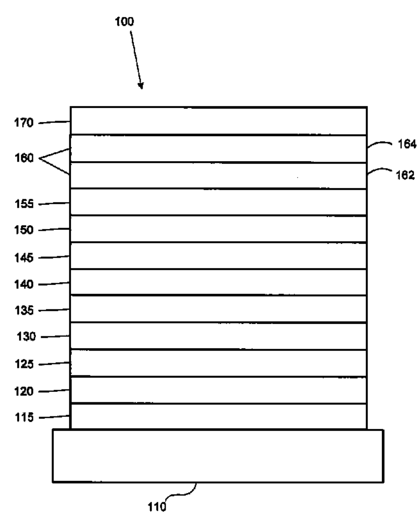
(57) **ABSTRACT**

Novel diarylamino phenyl carbazole compounds are provided. By appropriately selecting the nature of the diarylamino substituent and the substitution on the carbazole nitrogen, compounds with appropriate HOMO and LUMO energies can be obtained for use as materials in a secondary hole transport layer.

19 Claims, 3 Drawing Sheets



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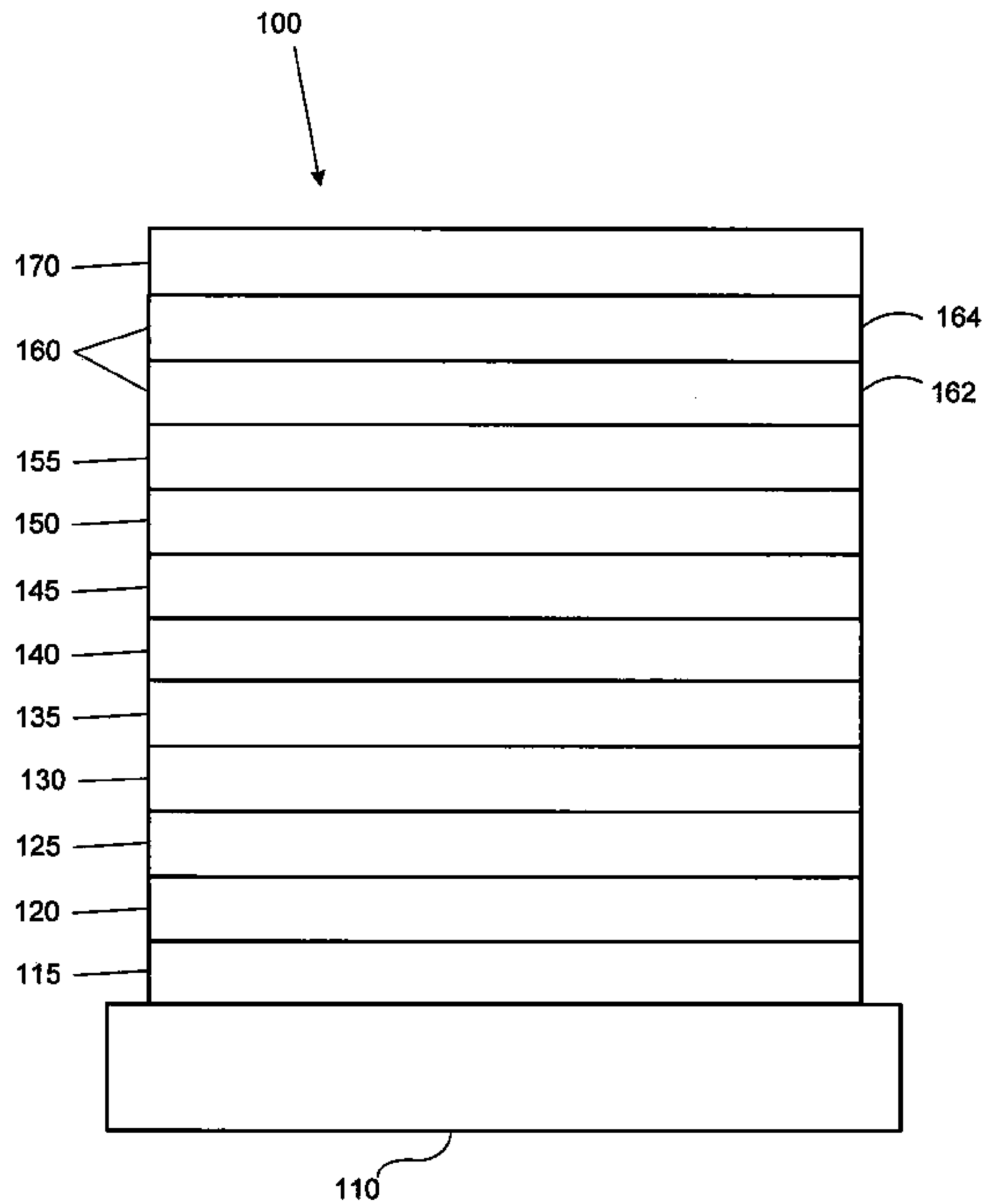


FIGURE 1

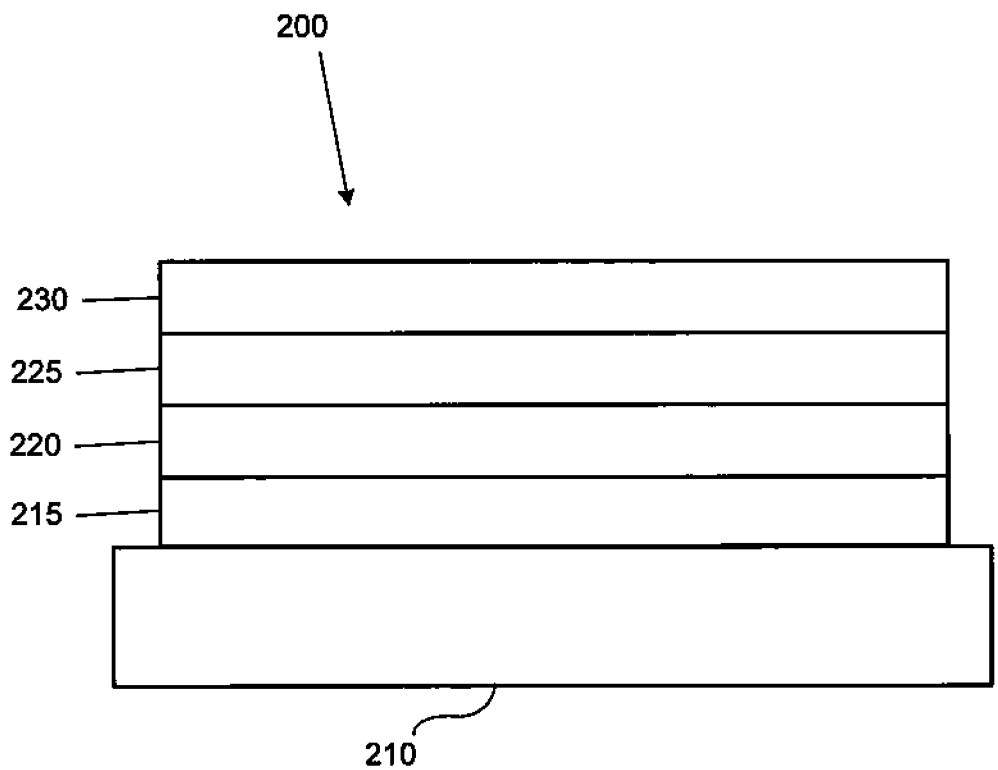
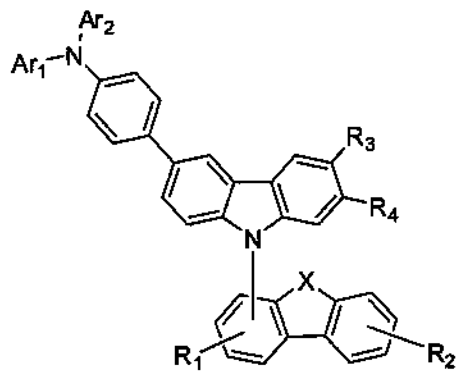


FIGURE 2



Formula I

FIGURE 3

SECONDARY HOLE TRANSPORTING LAYER WITH DIARYLAMINO-PHENYL-CARBAZOLE COMPOUNDS

The claimed invention was made by, on behalf of, and/or in connection with one or more of the following parties to a joint university corporation research agreement: Regents of the University of Michigan, Princeton University, The University of Southern California, and the Universal Display Corporation. The agreement was in effect on and before the date the claimed invention was made, and the claimed invention was made as a result of activities undertaken within the scope of the agreement.

FIELD OF THE INVENTION

The present invention relates to novel diarylamino phenyl carbazole compounds. In particular, these compounds are useful as materials that can be incorporated into a secondary hole transport layer in OLED devices.

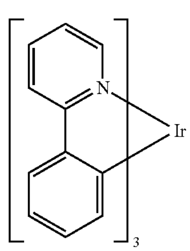
BACKGROUND

Opto-electronic devices that make use of organic materials are becoming increasingly desirable for a number of reasons. Many of the materials used to make such devices are relatively inexpensive, so organic opto-electronic devices have the potential for cost advantages over inorganic devices. In addition, the inherent properties of organic materials, such as their flexibility, may make them well suited for particular applications such as fabrication on a flexible substrate. Examples of organic opto-electronic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors. For OLEDs, the organic materials may have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants.

OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting. Several OLED materials and configurations are described in U.S. Pat. Nos. 5,844,363, 6,303,238, and 5,707,745, which are incorporated herein by reference in their entirety.

One application for phosphorescent emissive molecules is a full color display. Industry standards for such a display call for pixels adapted to emit particular colors, referred to as "saturated" colors. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art.

One example of a green emissive molecule is tris(2-phenylpyridine) iridium, denoted $Ir(ppy)_3$, which has the following structure:



In this, and later figures herein, we depict the dative bond from nitrogen to metal (here, Ir) as a straight line.

As used herein, the term "organic" includes polymeric materials as well as small molecule organic materials that may be used to fabricate organic opto-electronic devices. "Small molecule" refers to any organic material that is not a polymer, and "small molecules" may actually be quite large. Small molecules may include repeat units in some circumstances. For example, using a long chain alkyl group as a substituent does not remove a molecule from the "small molecule" class. Small molecules may also be incorporated into polymers, for example as a pendent group on a polymer backbone or as a part of the backbone. Small molecules may also serve as the core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety. The core moiety of a dendrimer may be a fluorescent or phosphorescent small molecule emitter. A dendrimer may be a "small molecule," and it is believed that all dendrimers currently used in the field of OLEDs are small molecules.

As used herein, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. Where a first layer is described as "disposed over" a second layer, the first layer is disposed further away from substrate. There may be other layers between the first and second layer, unless it is specified that the first layer is "in contact with" the second layer. For example, a cathode may be described as "disposed over" an anode, even though there are various organic layers in between.

As used herein, "solution processible" means capable of being dissolved, dispersed, or transported in and/or deposited from a liquid medium, either in solution or suspension form.

A ligand may be referred to as "photoactive" when it is believed that the ligand directly contributes to the photoactive properties of an emissive material. A ligand may be referred to as "ancillary" when it is believed that the ligand does not contribute to the photoactive properties of an emissive material, although an ancillary ligand may alter the properties of a photoactive ligand.

As used herein, and as would be generally understood by one skilled in the art, a first "Highest Occupied Molecular Orbital" (HOMO) or "Lowest Unoccupied Molecular Orbital" (LUMO) energy level is "greater than" or "higher than" a second HOMO or LUMO energy level if the first energy level is closer to the vacuum energy level. Since ionization potentials (IP) are measured as a negative energy relative to a vacuum level, a higher HOMO energy level corresponds to an IP having a smaller absolute value (an IP that is less negative). Similarly, a higher LUMO energy level corresponds to an electron affinity (EA) having a smaller absolute value (an EA that is less negative). On a conventional energy level diagram, with the vacuum level at the top, the LUMO energy level of a material is higher than the HOMO energy level of the same material. A "higher" HOMO or LUMO energy level appears closer to the top of such a diagram than a "lower" HOMO or LUMO energy level.

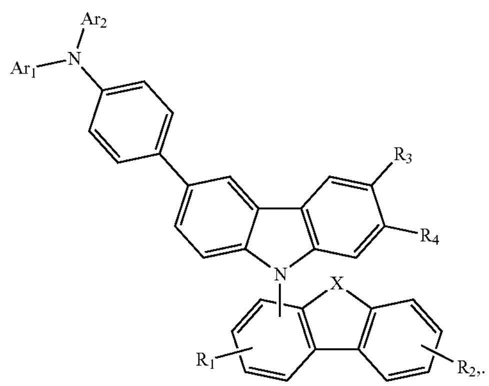
As used herein, and as would be generally understood by one skilled in the art, a first work function is "greater than" or "higher than" a second work function if the first work function has a higher absolute value. Because work functions are generally measured as negative numbers relative to vacuum level, this means that a "higher" work function is more negative. On a conventional energy level diagram, with the vacuum level at the top, a "higher" work function is illustrated as further away from the vacuum level in the downward direction. Thus, the definitions of HOMO and LUMO energy levels follow a different convention than work functions.

More details on OLEDs, and the definitions described above, can be found in U.S. Pat. No. 7,279,704, which is incorporated herein by reference in its entirety.

SUMMARY OF THE INVENTION

In one aspect, a compound having the formula I is provided:

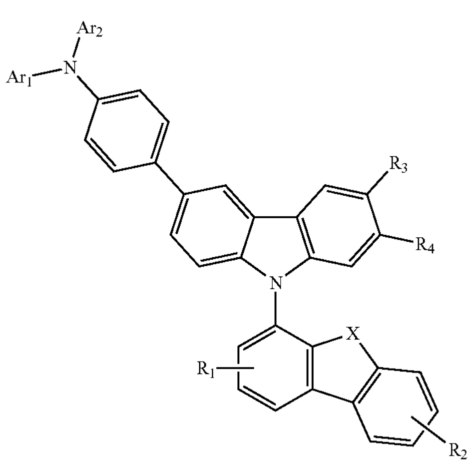
Formula I



In the compound of Formula I, Ar_1 and Ar_2 are independently selected from the group consisting of aryl and heteroaryl, X is selected from the group consisting of O, S, and Se, R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfanyl, sulfonyl, phosphino, and combinations thereof.

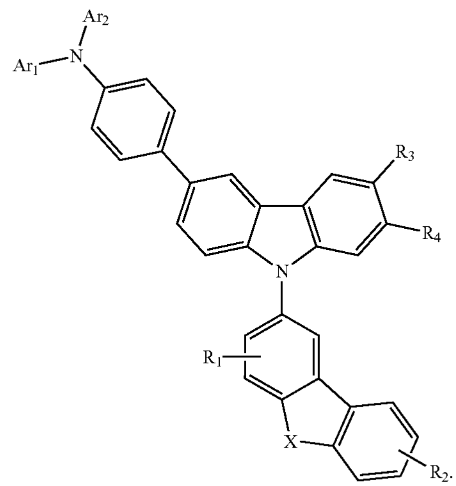
In one aspect, R_3 and R_4 are independently selected from the group consisting of alkyl, heteroalkyl, arylalkyl, aryl, and heteroaryl. In one aspect, R_3 and R_4 are hydrogen or deuterium.

In one aspect, the compound has the formula:

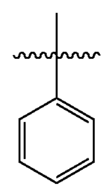
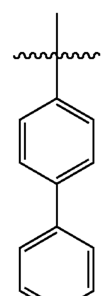
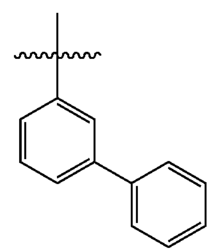
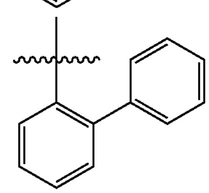
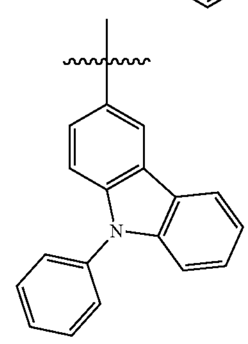
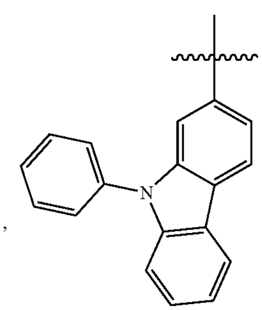
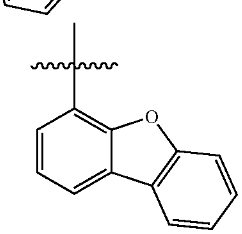
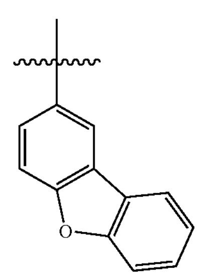


or

-continued



In one aspect, Ar_{1l} and Ar_2 are independently selected from the group consisting of:

,
,
,
,
,
,
,
,

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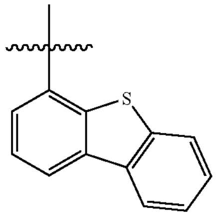
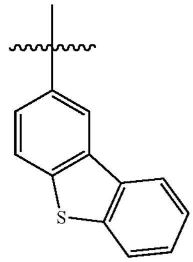
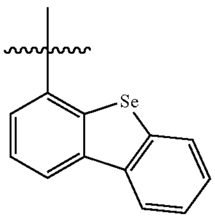
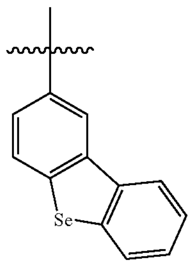
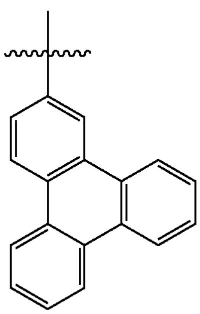
,

,

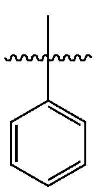
,

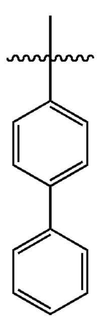


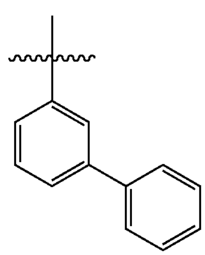
and

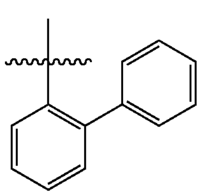
.

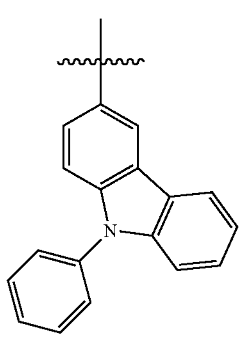
In one aspect, A_1 and Ar_2 are independently selected from the group consisting of:

,

,

,

,

,

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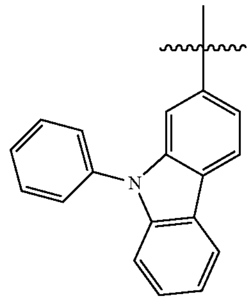
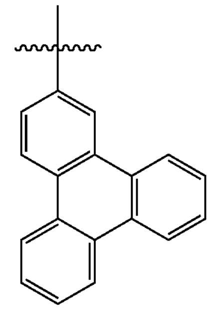
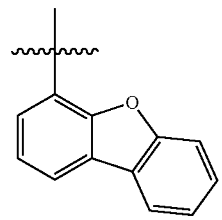
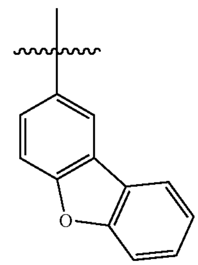
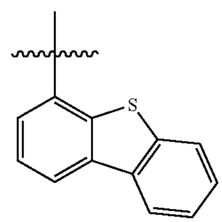
, and

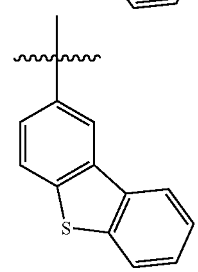
.

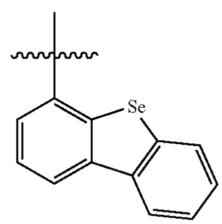
In one aspect, A_1 and Ar_2 are independently selected from the group consisting of:

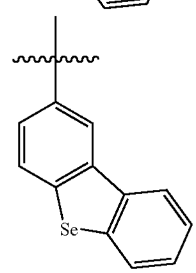
,

,

,

,

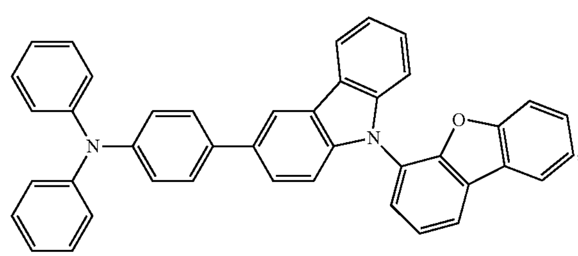
, and

.

In one aspect, X is O or S. In one aspect, A_1 and Ar_2 are aryl.

In one aspect, the compound is selected from the group consisting of:

Compound 7

,

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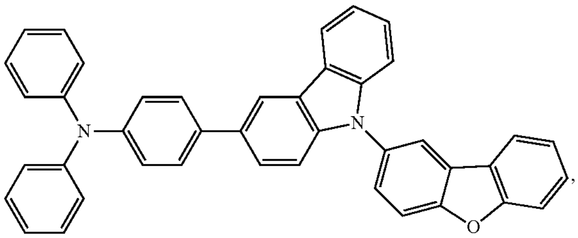
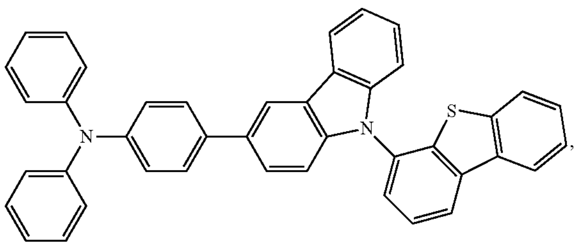
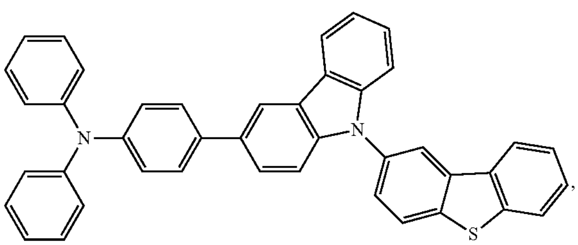
Compound 8



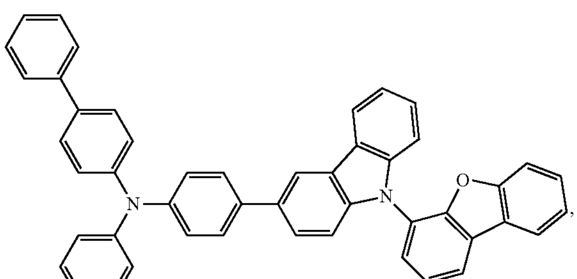
Compound 9



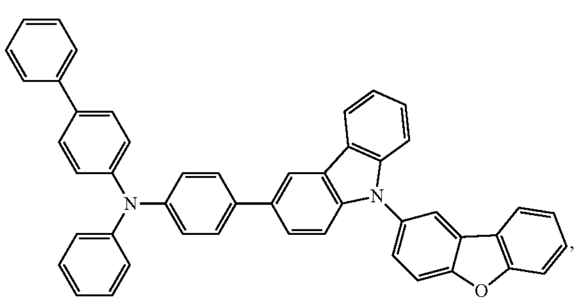
Compound 10



Compound 20



Compound 21



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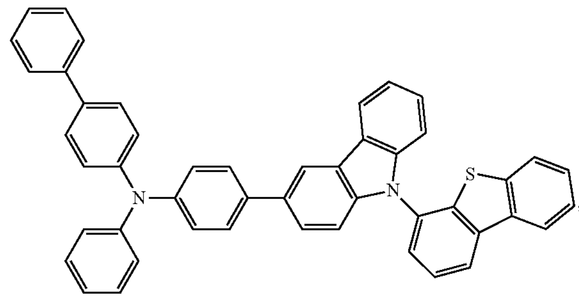
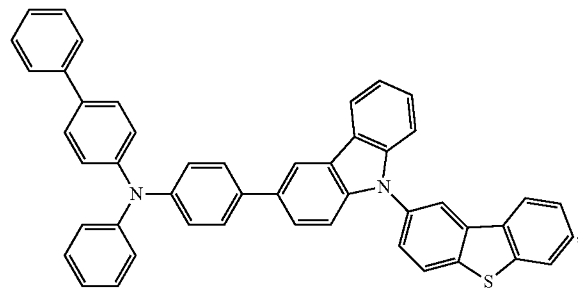
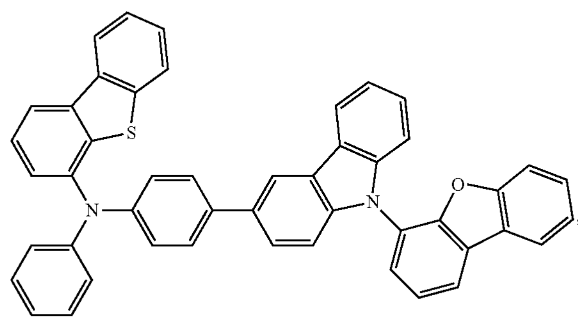
Compound 22



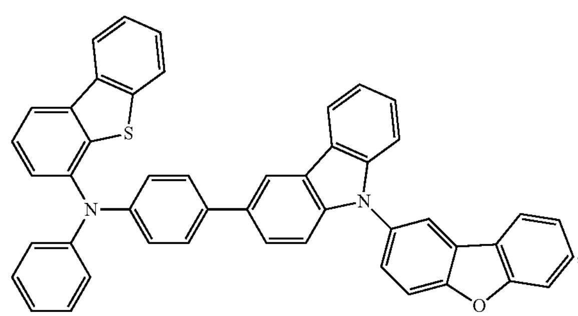
Compound 23



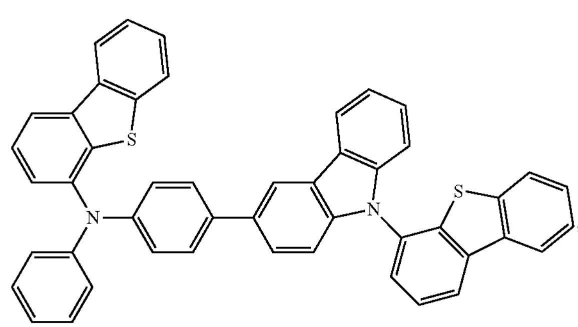
Compound 111



Compound 112



Compound 113



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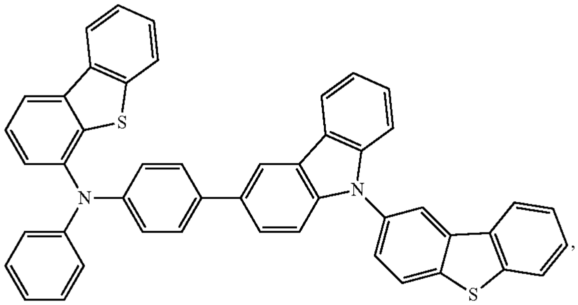
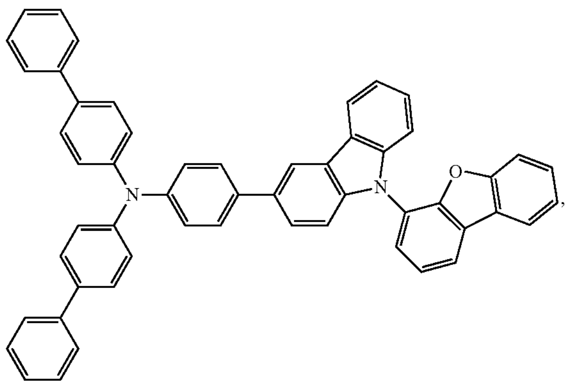
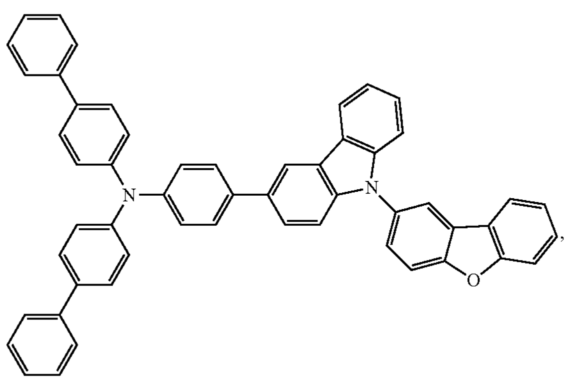
Compound 114



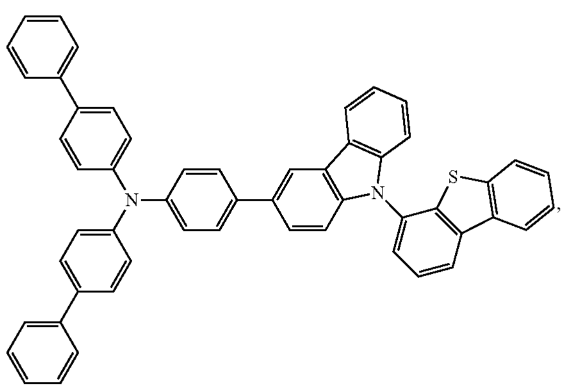
Compound 176



Compound 177



Compound 178



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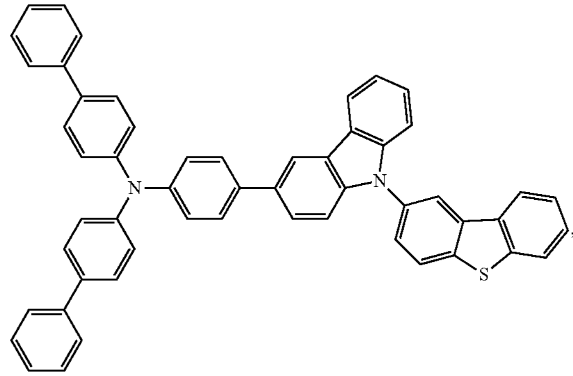
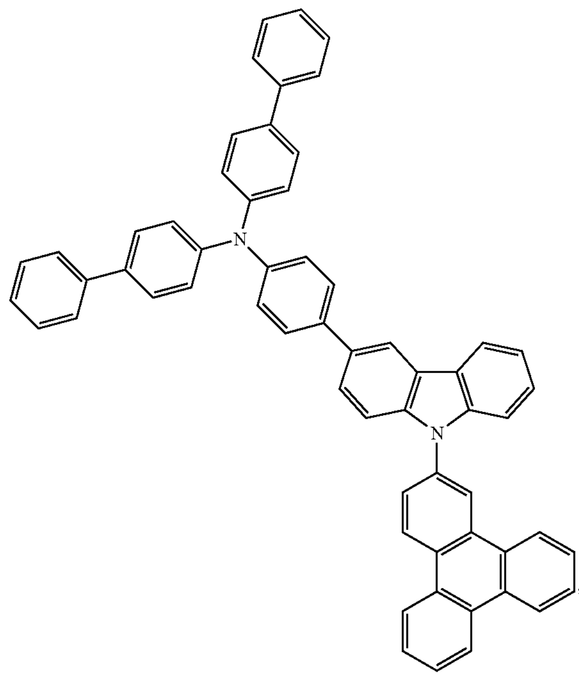
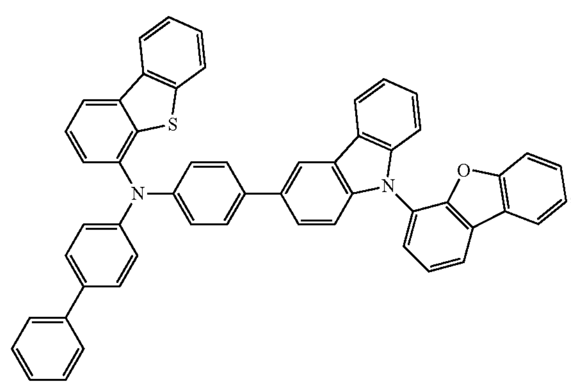
Compound 179



Compound 182



Compound 267



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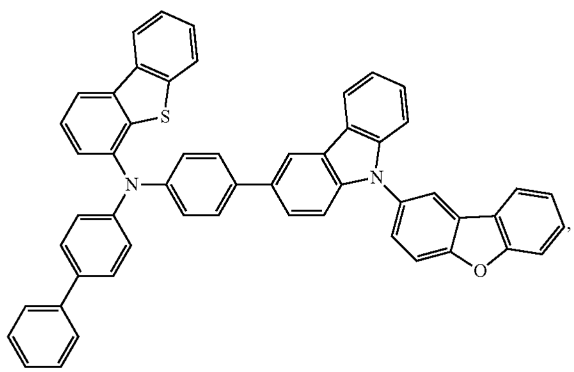
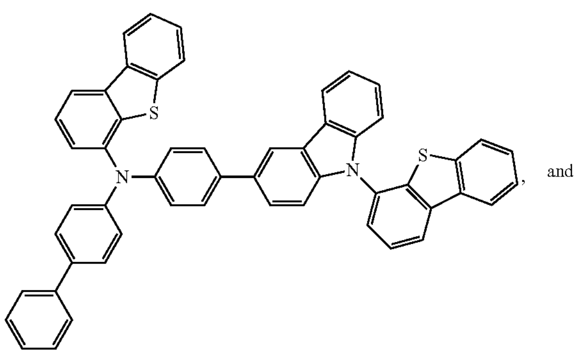
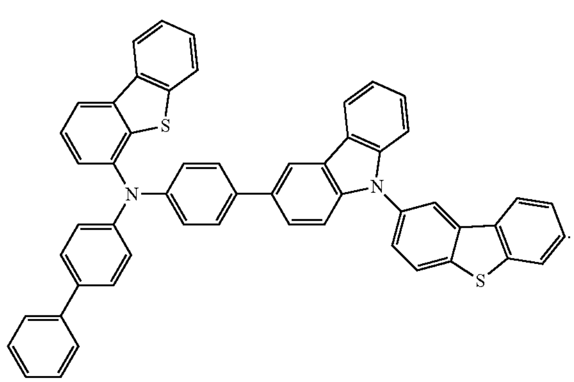
Compound 268



Compound 269

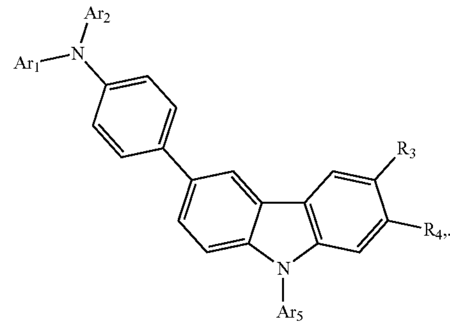


Compound 270



In one aspect, a first device is provided. The first device comprises an organic light emitting device, further comprising: an anode, a cathode, a hole injection layer disposed between the anode and the emissive layer, a first hole transport layer disposed between the hole injection layer and the emissive layer, and a second hole transport layer disposed between the first hole transport layer and the emissive layer, and wherein the second hole transport layer comprises a compound of formula:

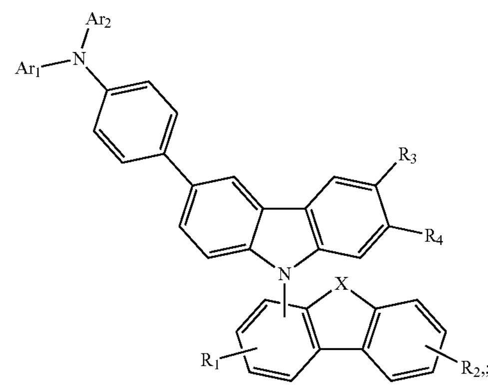
Formula II



In the compound of Formula II, Ar_1, Ar_2, and Ar_5 are independently selected from the group consisting of aryl and heteroaryl and R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

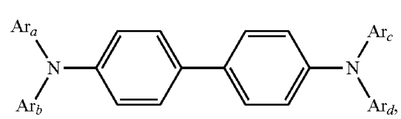
In one aspect, the compound has the formula:

Formula I



wherein X is selected from the group consisting of O, S, and Se, wherein R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and wherein R_1 and R_2 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

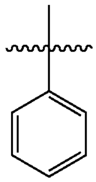
In one aspect, the second hole transport layer is disposed adjacent to the first hole transport layer. In one aspect, the first hole transport layer is thicker than the second hole transport layer. In one aspect, the first hole transport layer comprises a compound with the formula:



wherein Ar_a, Ar_b, Ar_c and Ar_d are independently selected from the group consisting of aryl and heteroaryl.

In one aspect, the triplet energy of the compound of Formula II is higher than the emission energy of the emissive layer.

In one aspect, Ar_1, Ar_2 and Ar_5 are independently selected from the group consisting of: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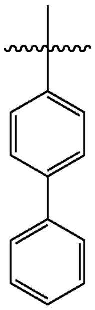
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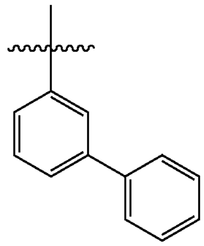
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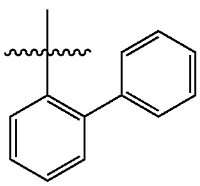
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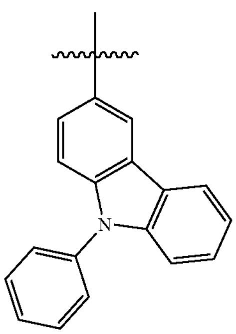
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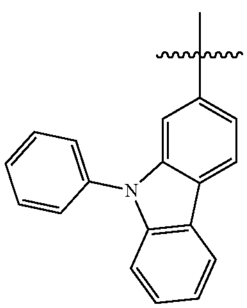
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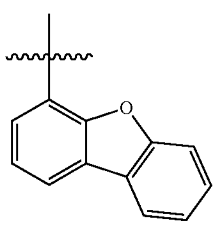

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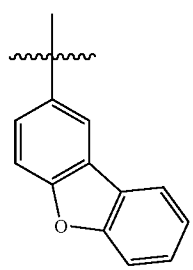

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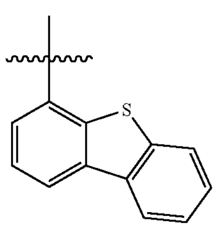

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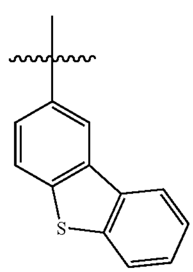

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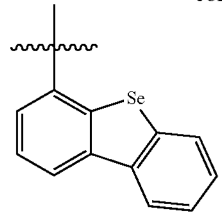

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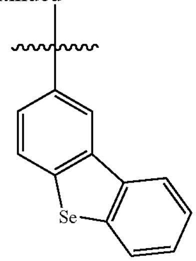

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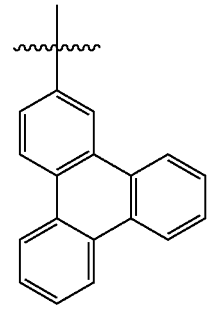
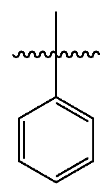

.

In one aspect, Ar_1 and Ar_2 are independently selected from the group consisting of: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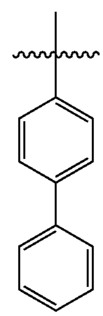
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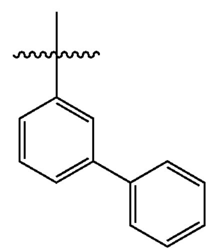
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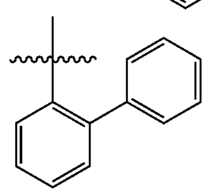
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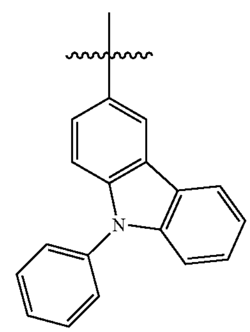

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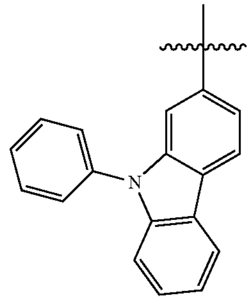
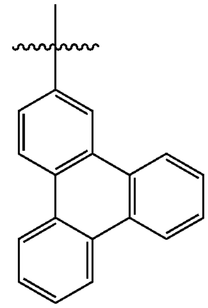
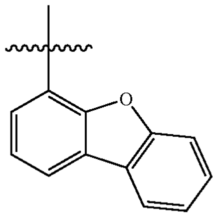
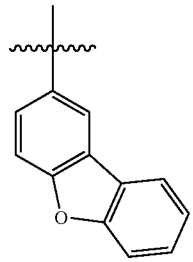
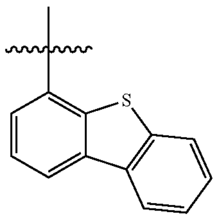
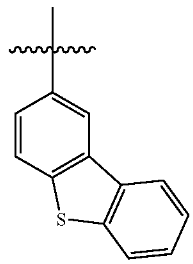
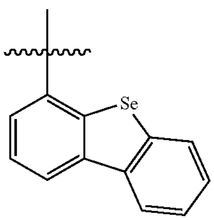
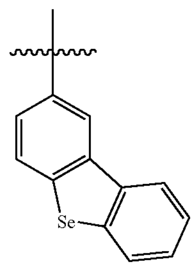
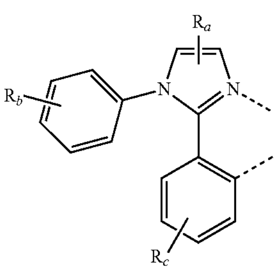
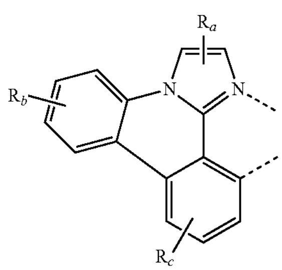
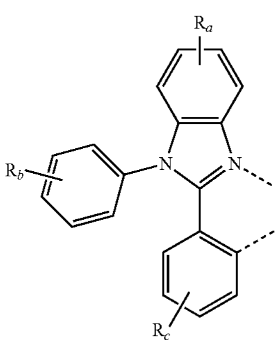
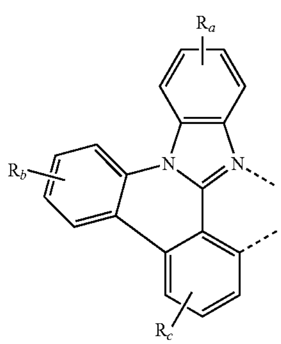


, and

.

In one aspect, Ar_1 and Ar_2 are independently selected from the group consisting of:

,
,
,
,
, and
.

In one aspect, the first device further comprises a first dopant material that is an emissive dopant comprising a transition metal complex having at least one ligand or part of the ligand if the ligand is more than bidentate selected from the group consisting of:

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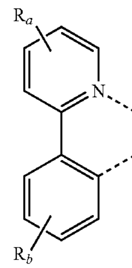
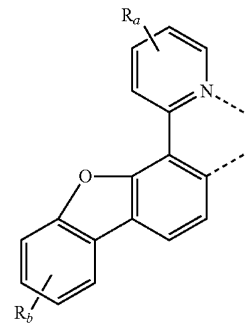
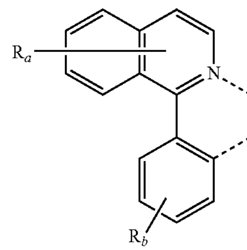
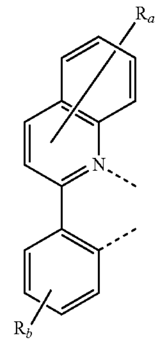
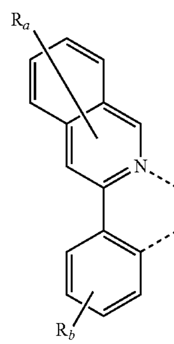
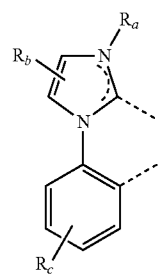
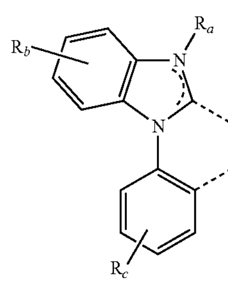
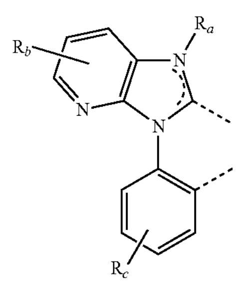
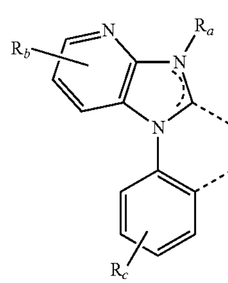
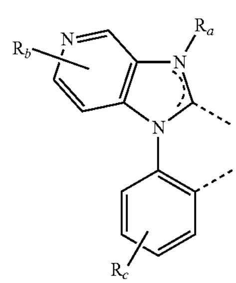

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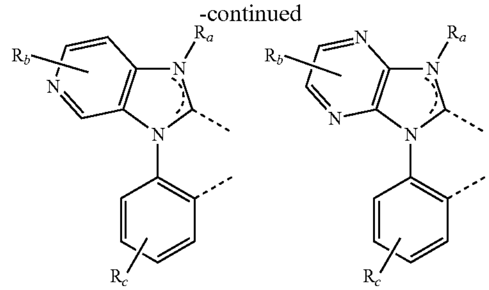
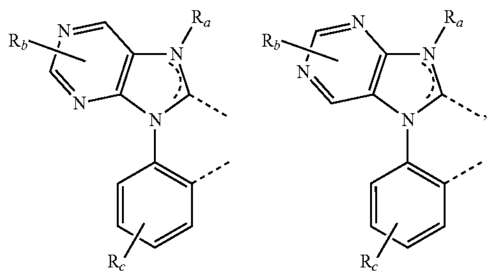
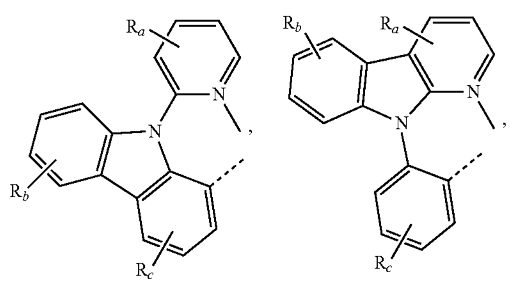
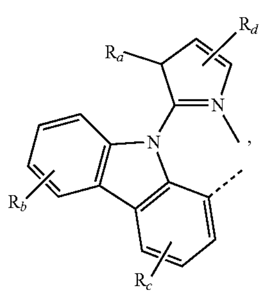






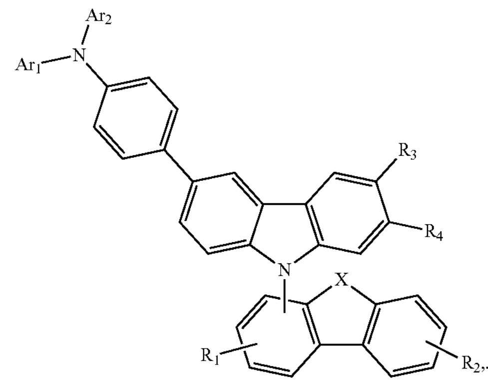
and



wherein R_a, R_b, R_c, and R_d may represent mono, di, tri, or tetra substitution, or no substitution and wherein R_a, R_b, R_c, and R_d are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, and wherein two adjacent substituents of R_a, R_b, R_c, and R_d are optionally joined to form a fused ring or form a multidentate ligand.

In one aspect, the first device is a consumer product. In one aspect, the first device is an organic light-emitting device. In one aspect, the first device comprises a lighting panel. In one aspect, a first device comprising an organic light emitting device, further comprising an anode, a cathode, a first organic layer disposed between the anode and the cathode, and wherein the first organic layer comprises a compound of formula:

Formula I



In the compound of Formula I, Ar_1 and Ar_2 are independently selected from the group consisting of aryl and heteroaryl, X is selected from the group consisting of O, S, and Se, R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one aspect, the first organic layer is an emissive layer. In one aspect, the emissive layer is a phosphorescent emissive layer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an organic light emitting device.

FIG. **2** shows an inverted organic light emitting device that does not have a separate electron transport layer.

FIG. **3** shows a compound of Formula I.

DETAILED DESCRIPTION

Generally, an OLED comprises at least one organic layer disposed between and electrically connected to an anode and a cathode. When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer(s). The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize on the same molecule, an "exciton," which is a localized electron-hole pair having an excited energy state, is formed. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable.

The initial OLEDs used emissive molecules that emitted light from their singlet states ("fluorescence") as disclosed, for example, in U.S. Pat. No. 4,769,292, which is incorporated by reference in its entirety. Fluorescent emission generally occurs in a time frame of less than 10 nanoseconds.

More recently, OLEDs having emissive materials that emit light from triplet states ("phosphorescence") have been demonstrated. Baldo et al., "Highly Efficient Phosphorescent Emission from Organic Electroluminescent Devices," Nature, vol. 395, 151-154, 1998; ("Baldo-I") and Baldo et al., "Very high-efficiency green organic light-emitting devices based on electrophosphorescence," Appl. Phys. Lett., vol. 75, No. 3, 4-6 (1999) ("Baldo-II"), which are incorporated by reference in their entireties. Phosphorescence is described in more detail in U.S. Pat. No. 7,279,704 at cols. 5-6, which are incorporated by reference.

FIG. **1** shows an organic light emitting device **100**. The figures are not necessarily drawn to scale. Device **100** may include a substrate **110**, an anode **115**, a hole injection layer **120**, a hole transport layer **125**, an electron blocking layer **130**, an emissive layer **135**, a hole blocking layer **140**, an electron transport layer **145**, an electron injection layer **150**, a protective layer **155**, a cathode **160**, and a barrier layer **170**. Cathode **160** is a compound cathode having a first conductive layer **162** and a second conductive layer **164**. Device **100** may be fabricated by depositing the layers described, in order. The properties and functions of these various layers, as well as example materials, are described in more detail in U.S. Pat. No. 7,279,704 at cols. 6-10, which are incorporated by reference.

More examples for each of these layers are available. For example, a flexible and transparent substrate-anode combination is disclosed in U.S. Pat. No. 5,844,363, which is incorporated by reference in its entirety. An example of a p-doped hole transport layer is m-MTDATA doped with F.sub.4-TCNQ at a molar ratio of 50:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. Examples of emissive and host materials are disclosed in U.S. Pat. No. 6,303,238 to Thompson et al., which is incorporated by reference in its entirety. An example of an n-doped electron transport layer is BPhen doped with Li at a molar ratio of 1:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. U.S. Pat. Nos. 5,703,436 and 5,707,745, which are incorporated by reference in their entireties, disclose examples of cathodes including compound cathodes having a thin layer of metal such as Mg:Ag with an overlying transparent, electrically-conductive, sputter-deposited ITO layer. The theory and use of blocking layers is described in more detail in U.S. Pat. No. 6,097,147 and U.S. Patent Application Publication No. 2003/0230980, which are incorporated by reference in their entireties. Examples of injection layers are provided in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety. A description of protective layers may be found in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety.

FIG. **2** shows an inverted OLED **200**. The device includes a substrate **210**, a cathode **215**, an emissive layer **220**, a hole transport layer **225**, and an anode **230**. Device **200** may be fabricated by depositing the layers described, in order. Because the most common OLED configuration has a cathode disposed over the anode, and device **200** has cathode **215** disposed under anode **230**, device **200** may be referred to as an "inverted" OLED. Materials similar to those described with respect to device **100** may be used in the corresponding layers of device **200**. FIG. **2** provides one example of how some layers may be omitted from the structure of device **100**.

The simple layered structure illustrated in FIGS. **1** and **2** is provided by way of non-limiting example, and it is understood that embodiments of the invention may be used in connection with a wide variety of other structures. The specific materials and structures described are exemplary in nature, and other materials and structures may be used. Functional OLEDs may be achieved by combining the various layers described in different ways, or layers may be omitted entirely, based on design, performance, and cost factors. Other layers not specifically described may also be included. Materials other than those specifically described may be used. Although many of the examples provided herein describe various layers as comprising a single material, it is understood that combinations of materials, such as a mixture of host and dopant, or more generally a mixture, may be used. Also, the layers may have various sublayers. The names given to the various layers herein are not intended to be strictly limiting. For example, in device **200**, hole transport layer **225** transports holes and injects holes into emissive layer **220**, and may be described as a hole transport layer or a hole injection layer. In one embodiment, an OLED may be described as having an "organic layer" disposed between a cathode and an anode. This organic layer may comprise a single layer, or may further comprise multiple layers of different organic materials as described, for example, with respect to FIGS. **1** and **2**.

Structures and materials not specifically described may also be used, such as OLEDs comprised of polymeric materials (PLEDs) such as disclosed in U.S. Pat. No. 5,247,190 to Friend et al., which is incorporated by reference in its entirety. By way of further example, OLEDs having a single organic layer may be used. OLEDs may be stacked, for example as described in U.S. Pat. No. 5,707,745 to Forrest et al, which is incorporated by reference in its entirety. The OLED structure may deviate from the simple layered structure illustrated in FIGS. **1** and **2**. For example, the substrate may include an angled reflective surface to improve out-coupling, such as a mesa structure as described in U.S. Pat. No. 6,091,195 to Forrest et al., and/or a pit structure as described in U.S. Pat. No. 5,834,893 to Bulovic et al., which are incorporated by reference in their entireties.

Unless otherwise specified, any of the layers of the various embodiments may be deposited by any suitable method. For the organic layers, preferred methods include thermal evaporation, ink-jet, such as described in U.S. Pat. Nos. 6,013,982 and 6,087,196, which are incorporated by reference in their entireties, organic vapor phase deposition (OVPD), such as described in U.S. Pat. No. 6,337,102 to Forrest et al., which is incorporated by reference in its entirety, and deposition by organic vapor jet printing (OVJP), such as described in U.S. patent application Ser. No. 10/233,470, which is incorporated by reference in its entirety. Other suitable deposition methods include spin coating and other solution based processes. Solution based processes are preferably carried out in nitrogen or an inert atmosphere. For the other layers, preferred methods include thermal evaporation. Preferred patterning methods include deposition through a mask, cold welding such as described in U.S. Pat. Nos. 6,294,398 and 6,468,819, which are incorporated by reference in their entireties, and patterning associated with some of the deposition methods such as ink-jet and OVJD. Other methods may also be used. The materials to be deposited may be modified to make them compatible with a particular deposition method. For example, substituents such as alkyl and aryl groups, branched or unbranched, and preferably containing at least 3 carbons, may be used in small molecules to enhance their ability to undergo solution processing. Substituents having 20 carbons or more may be used, and 3-20 carbons is a preferred range. Materials with asymmetric structures may have better solution processibility than those having symmetric structures, because asymmetric materials may have a lower tendency to recrystallize. Dendrimer substituents may be used to enhance the ability of small molecules to undergo solution processing.

Devices fabricated in accordance with embodiments of the present invention may further optionally comprise a barrier layer. One purpose of the barrier layer is to protect the electrodes and organic layers from damaging exposure to harmful species in the environment including moisture, vapor and/or gases, etc. The bather layer may be deposited over, under or next to a substrate, an electrode, or over any other parts of a device including an edge. The barrier layer may comprise a single layer, or multiple layers. The barrier layer may be formed by various known chemical vapor deposition techniques and may include compositions having a single phase as well as compositions having multiple phases. Any suitable material or combination of materials may be used for the barrier layer. The barrier layer may incorporate an inorganic or an organic compound or both. The preferred barrier layer comprises a mixture of a polymeric material and a non-polymeric material as described in U.S. Pat. No. 7,968,146, PCT Pat. Application Nos. PCT/US2007/023098 and PCT/US2009/042829, which are herein incorporated by reference in their entireties. To be considered a "mixture", the aforesaid polymeric and non-polymeric materials comprising the barrier layer should be deposited under the same reaction conditions and/or at the same time. The weight ratio of polymeric to non-polymeric material may be in the range of 95:5 to 5:95. The polymeric material and the non-polymeric material may be created from the same precursor material. In one example, the mixture of a polymeric material and a non-polymeric material consists essentially of polymeric silicon and inorganic silicon.

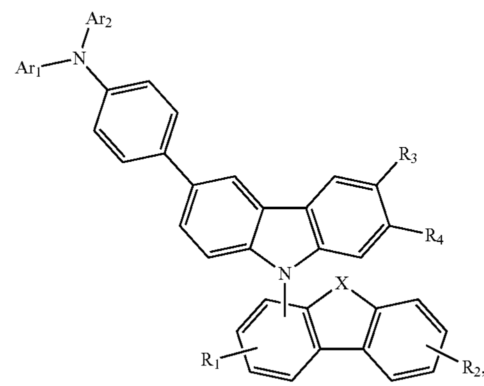
Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including flat panel displays, computer monitors, medical monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent displays, flexible displays, laser printers, telephones, cell phones, personal digital assistants (PDAs), laptop computers, digital cameras, camcorders, viewfinders, micro-displays, vehicles, a large area wall, theater or stadium screen, or a sign. Various control mechanisms may be used to control devices fabricated in accordance with the present invention, including passive matrix and active matrix. Many of the devices are intended for use in a temperature range comfortable to humans, such as 18 degrees C. to 30 degrees C., and more preferably at room temperature (20-25 degrees C.).

The materials and structures described herein may have applications in devices other than OLEDs. For example, other optoelectronic devices such as organic solar cells and organic photodetectors may employ the materials and structures. More generally, organic devices, such as organic transistors, may employ the materials and structures.

The terms halo, halogen, alkyl, cycloalkyl, alkenyl, alkynyl, arylkyl, heterocyclic group, aryl, aromatic group, and heteroaryl are known to the art, and are defined in U.S. Pat. No. 7,279,704 at cols. 31-32, which are incorporated herein by reference.

In one embodiment, a compound having the formula I is provided:

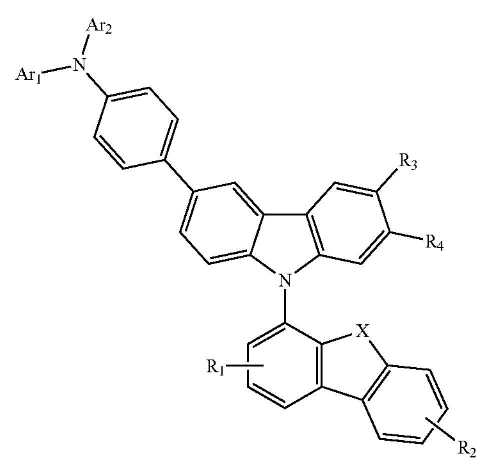
Formula I



In the compound of Formula I, Ar_1 and Ar_2 are independently selected from the group consisting of aryl and heteroaryl, X is selected from the group consisting of O, S, and Se, R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one embodiment, R_3 and R_4 are independently selected from the group consisting of alkyl, heteroalkyl, arylalkyl, aryl, and heteroaryl. In one embodiment, R_3 and R_4 are hydrogen or deuterium.

In one embodiment, the compound has the formula:



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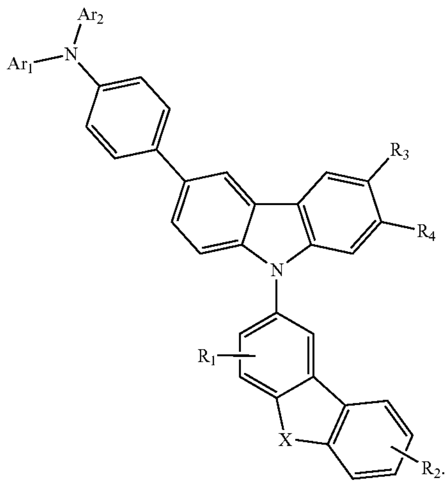
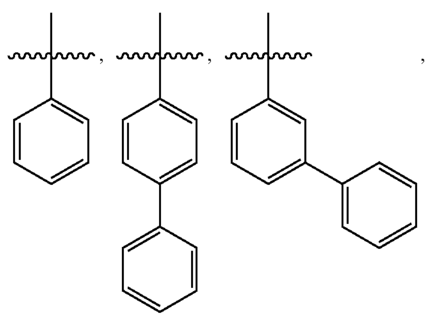
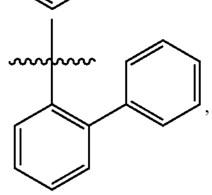
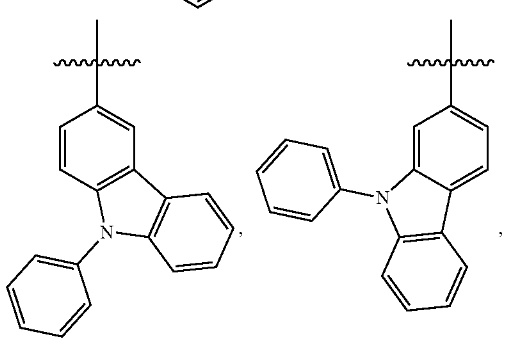
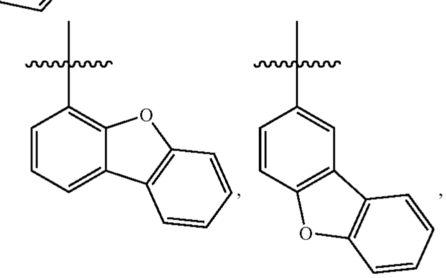


In one embodiment, A_1 and Ar_2 are independently selected from the group consisting of:









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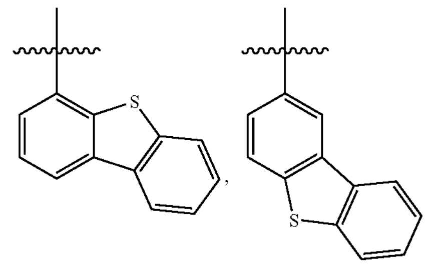

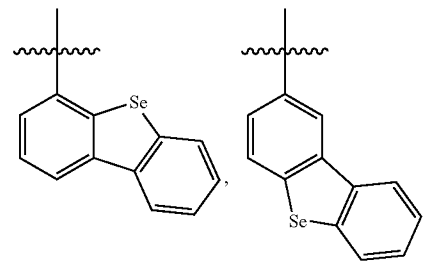

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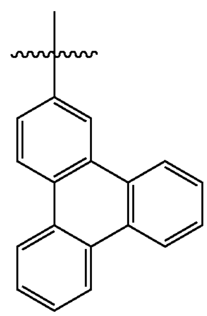
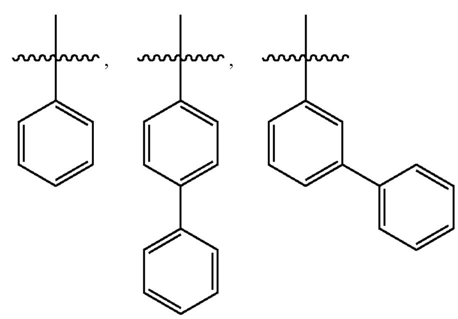
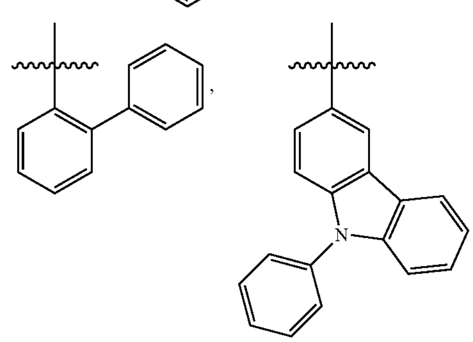


In one embodiment, Ar_1 and Ar_2 are independently selected from the group consisting of:





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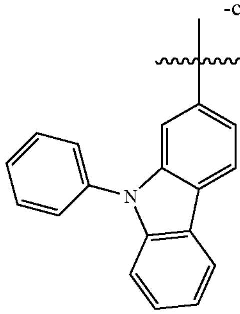

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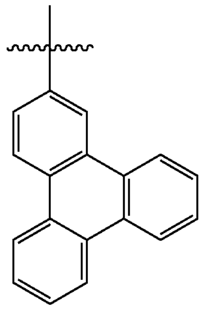

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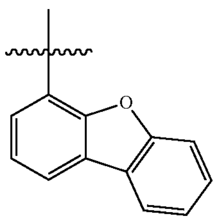
In one embodiment, Ar_1 and Ar_2 are independently selected from the group consisting of:



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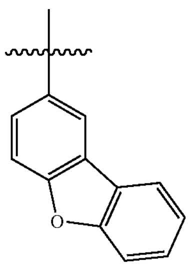

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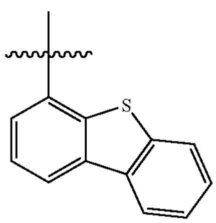
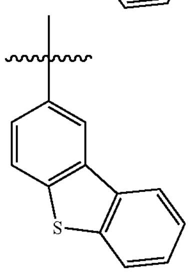
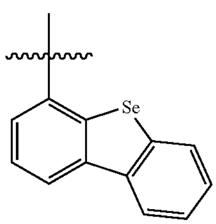


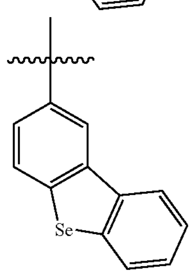
,



,



, and

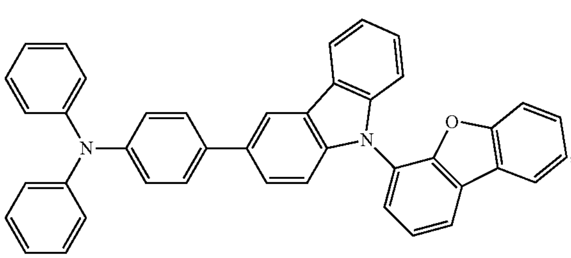


.

In one embodiment, X is O or S. In one embodiment, Ar_1 and Ar_2 are aryl.

In one embodiment, the compound is selected from the group consisting of:

Compound 7



,

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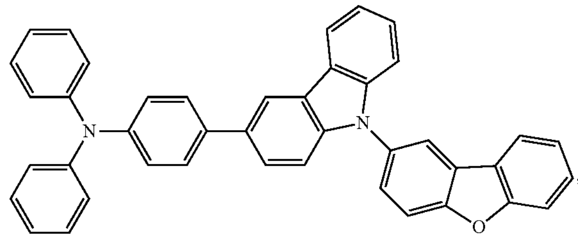
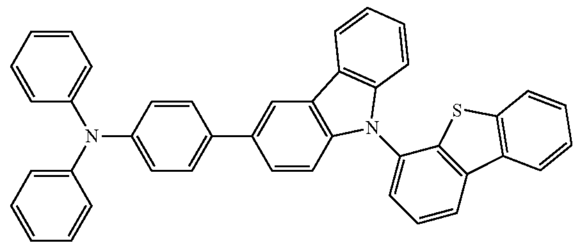
Compound 8



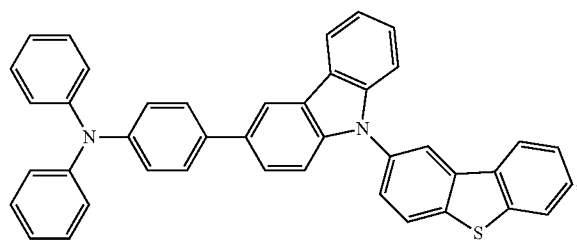
,

Compound 9



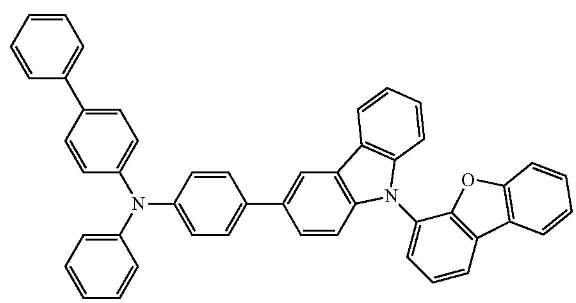
,

Compound 10



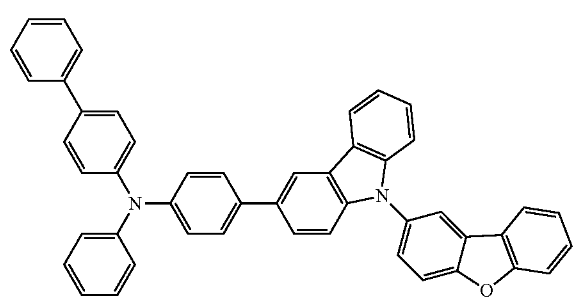
,

Compound 20



,

Compound 21



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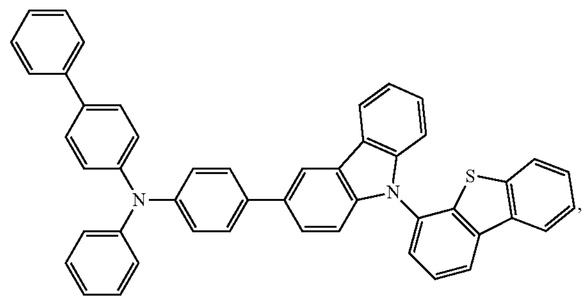
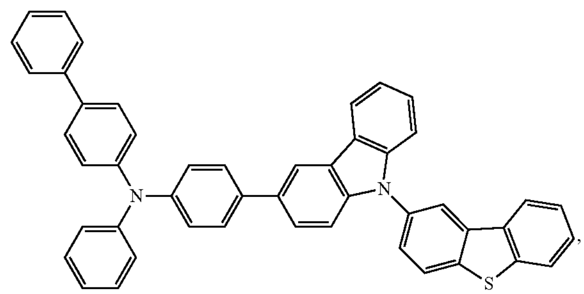
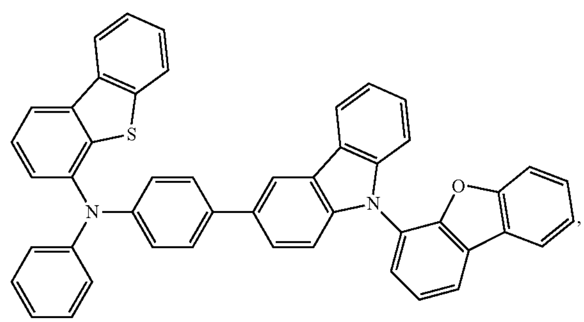
Compound 22



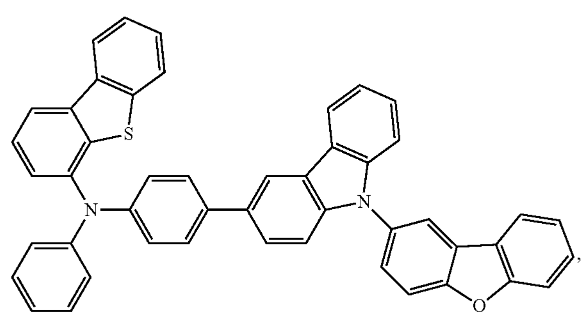
Compound 23



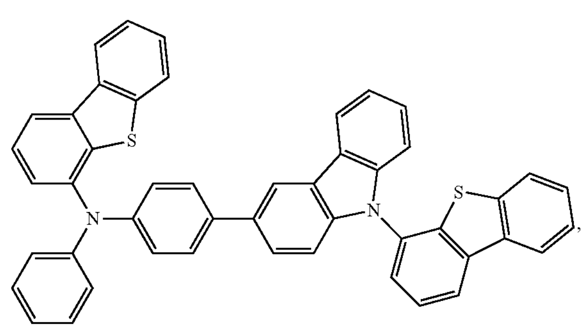
Compound 111



Compound 112



Compound 113



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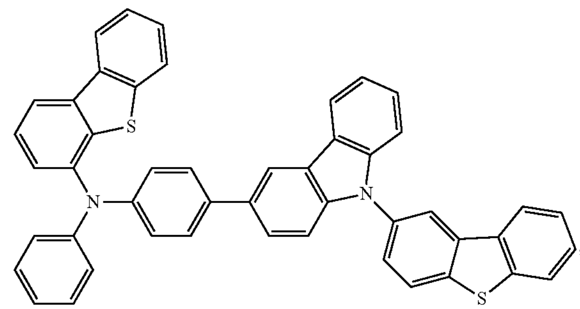
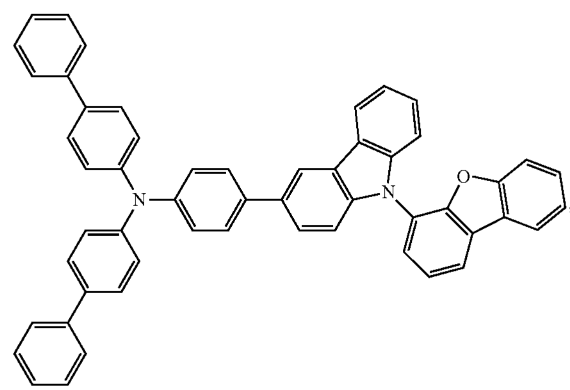
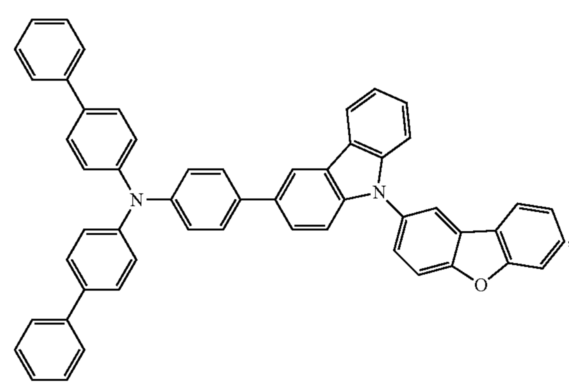
Compound 114



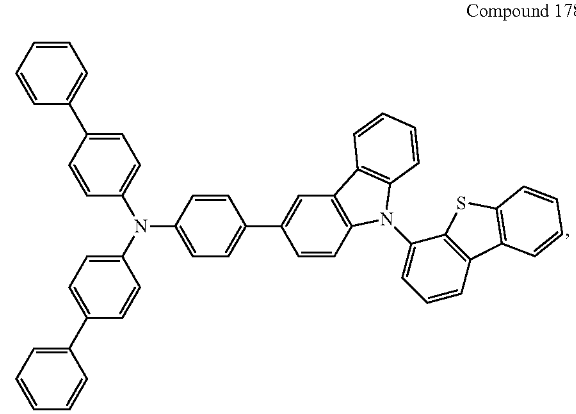
Compound 176



Compound 177



Compound 178



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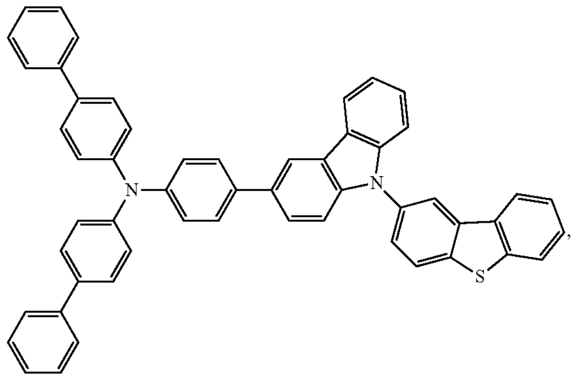
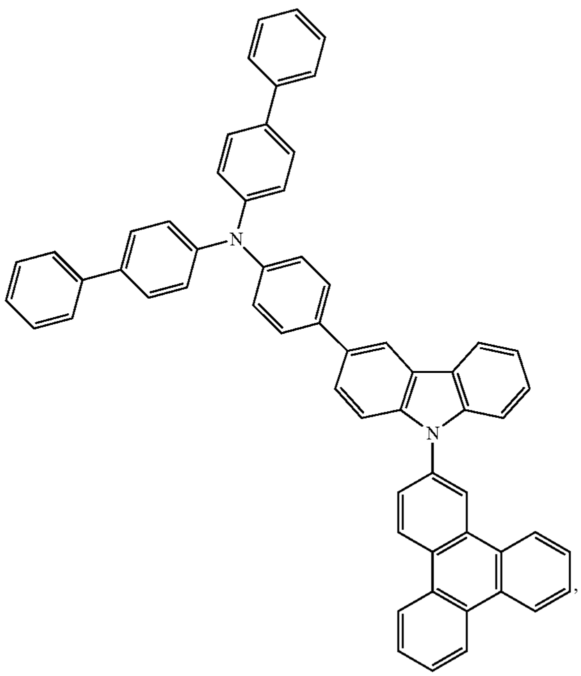
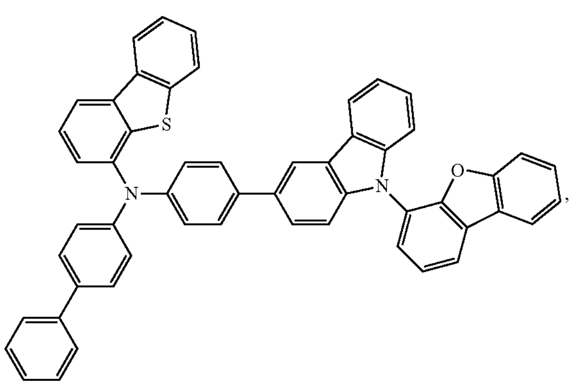
Compound 179



Compound 182



Compound 267



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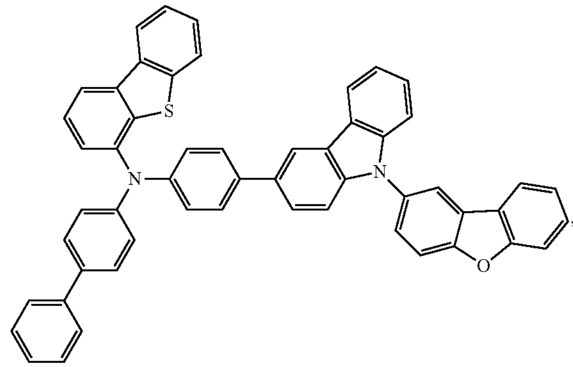
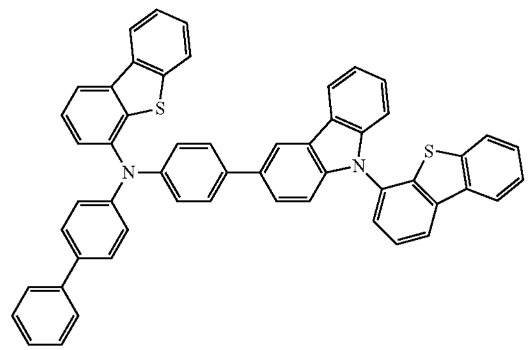
Compound 268

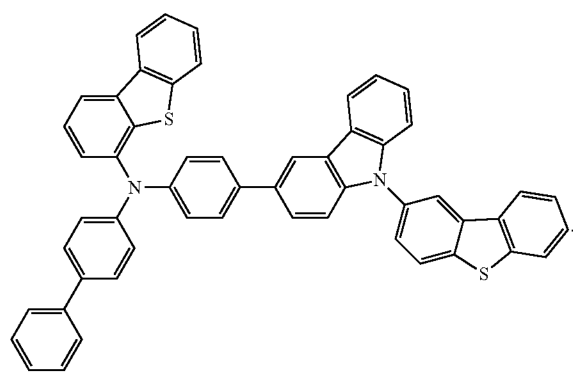


Compound 269



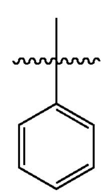
and

Compound 270



In some embodiments, the compounds are selected from the group consisting of Compound 1-Compound 1183 as depicted in Table 1. The list of substituents in Table 1 is as follows:

Ar_x-1



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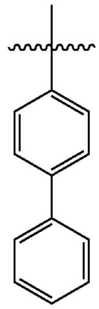
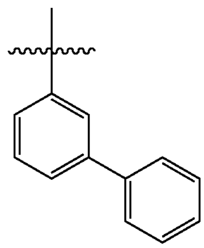
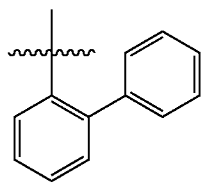
Ar_x-2



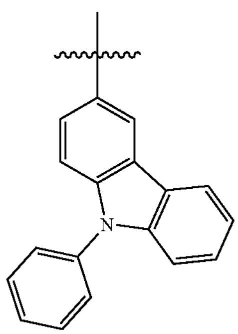
Ar_x-3



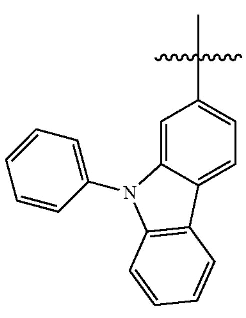
Ar_x-4



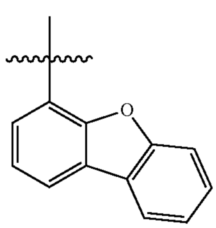
Ar_x-5



Ar_x-6



Ar_x-7



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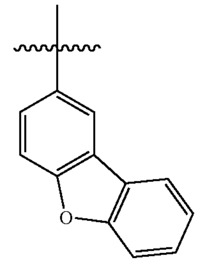
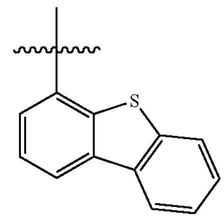
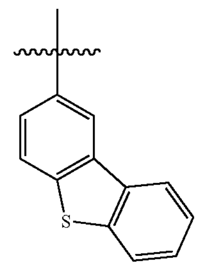
Ar_x-8



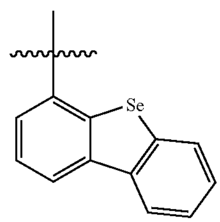
Ar_x-9



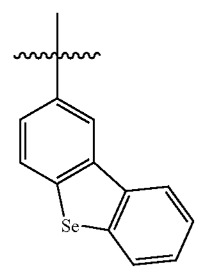
Ar_x-10



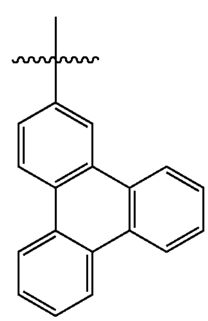
Ar_x-11



Ar_x-12



Ar_x-13



The subscript "x" in Ar_x depends on whether the group is Ar_1, Ar_2, or Ar_5.

		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-1	Ar_2-1	x													1
Ar_1-1	Ar_2-1		x												2
Ar_1-1	Ar_2-1			x											3
Ar_1-1	Ar_2-1				x										4
Ar_1-1	Ar_2-1					x									5
Ar_1-1	Ar_2-1						x								6
Ar_1-1	Ar_2-1							x							7
Ar_1-1	Ar_2-1								x						8
Ar_1-1	Ar_2-1									x					9
Ar_1-1	Ar_2-1										x				10
Ar_1-1	Ar_2-1											x			11
Ar_1-1	Ar_2-1												x		12
Ar_1-1	Ar_2-1													x	13
Ar_1-1	Ar_2-2	x													14
Ar_1-1	Ar_2-2		x												15
Ar_1-1	Ar_2-2			x											16
Ar_1-1	Ar_2-2				x										17
Ar_1-1	Ar_2-2					x									18
Ar_1-1	Ar_2-2						x								19
Ar_1-1	Ar_2-2							x							20
Ar_1-1	Ar_2-2								x						21
Ar_1-1	Ar_2-2									x					22
Ar_1-1	Ar_2-2										x				23
Ar_1-1	Ar_2-2											x			24
Ar_1-1	Ar_2-2												x		25
Ar_1-1	Ar_2-2													x	26
Ar_1-1	Ar_2-3	x													27
Ar_1-1	Ar_2-3		x												28
Ar_1-1	Ar_2-3			x											29
Ar_1-1	Ar_2-3				x										30
Ar_1-1	Ar_2-3					x									31
Ar_1-1	Ar_2-3						x								32
Ar_1-1	Ar_2-3							x							33
Ar_1-1	Ar_2-3								x						34
Ar_1-1	Ar_2-3									x					35
Ar_1-1	Ar_2-3										x				36
Ar_1-1	Ar_2-3											x			37
Ar_1-1	Ar_2-3												x		38
Ar_1-1	Ar_2-3													x	39
Ar_1-1	Ar_2-4	x													40
Ar_1-1	Ar_2-4		x												41
Ar_1-1	Ar_2-4			x											42
Ar_1-1	Ar_2-4				x										43
Ar_1-1	Ar_2-4					x									44
Ar_1-1	Ar_2-4						x								45
Ar_1-1	Ar_2-4							x							46
Ar_1-1	Ar_2-4								x						47
Ar_1-1	Ar_2-4									x					48
Ar_1-1	Ar_2-4										x				49
Ar_1-1	Ar_2-4											x			50
Ar_1-1	Ar_2-4												x		51
Ar_1-1	Ar_2-4													x	52
Ar_1-1	Ar_2-5	x													53
Ar_1-1	Ar_2-5		x												54
Ar_1-1	Ar_2-5			x											55
Ar_1-1	Ar_2-5				x										56
Ar_1-1	Ar_2-5					x									57
Ar_1-1	Ar_2-5						x								58
Ar_1-1	Ar_2-5							x							59
Ar_1-1	Ar_2-5								x						60
Ar_1-1	Ar_2-5									x					61
Ar_1-1	Ar_2-5										x				62
Ar_1-1	Ar_2-5											x			63
Ar_1-1	Ar_2-5												x		64
Ar_1-1	Ar_2-5													x	65
Ar_1-1	Ar_2-6	x													66
Ar_1-1	Ar_2-6		x												67
Ar_1-1	Ar_2-6			x											68
Ar_1-1	Ar_2-6				x										69
Ar_1-1	Ar_2-6					x									70
Ar_1-1	Ar_2-6						x								71
Ar_1-1	Ar_2-6							x							72
Ar_1-1	Ar_2-6								x						73
Ar_1-1	Ar_2-6									x					74
Ar_1-1	Ar_2-6										x				75
Ar_1-1	Ar_2-6											x			76

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-1	Ar_2-6												x		77
Ar_1-1	Ar_2-6													x	78
Ar_1-1	Ar_2-7	x													79
Ar_1-1	Ar_2-7		x												80
Ar_1-1	Ar_2-7			x											81
Ar_1-1	Ar_2-7				x										82
Ar_1-1	Ar_2-7					x									83
Ar_1-1	Ar_2-7						x								84
Ar_1-1	Ar_2-7							x							85
Ar_1-1	Ar_2-7								x						86
Ar_1-1	Ar_2-7									x					87
Ar_1-1	Ar_2-7										x				88
Ar_1-1	Ar_2-7											x			89
Ar_1-1	Ar_2-7												x		90
Ar_1-1	Ar_2-7													x	91
Ar_1-1	Ar_2-8	x													92
Ar_1-1	Ar_2-8		x												93
Ar_1-1	Ar_2-8			x											94
Ar_1-1	Ar_2-8				x										95
Ar_1-1	Ar_2-8					x									96
Ar_1-1	Ar_2-8						x								97
Ar_1-1	Ar_2-8							x							98
Ar_1-1	Ar_2-8								x						99
Ar_1-1	Ar_2-8									x					100
Ar_1-1	Ar_2-8										x				101
Ar_1-1	Ar_2-8											x			102
Ar_1-1	Ar_2-8												x		103
Ar_1-1	Ar_2-8													x	104
Ar_1-1	Ar_2-9	x													105
Ar_1-1	Ar_2-9		x												106
Ar_1-1	Ar_2-9			x											107
Ar_1-1	Ar_2-9				x										108
Ar_1-1	Ar_2-9					x									109
Ar_1-1	Ar_2-9						x								110
Ar_1-1	Ar_2-9							x							111
Ar_1-1	Ar_2-9								x						112
Ar_1-1	Ar_2-9									x					113
Ar_1-1	Ar_2-9										x				114
Ar_1-1	Ar_2-9											x			115
Ar_1-1	Ar_2-9												x		116
Ar_1-1	Ar_2-9													x	117
Ar_1-1	Ar_2-10	x													118
Ar_1-1	Ar_2-10		x												119
Ar_1-1	Ar_2-10			x											120
Ar_1-1	Ar_2-10				x										121
Ar_1-1	Ar_2-10					x									122
Ar_1-1	Ar_2-10						x								123
Ar_1-1	Ar_2-10							x							124
Ar_1-1	Ar_2-10								x						125
Ar_1-1	Ar_2-10									x					126
Ar_1-1	Ar_2-10										x				127
Ar_1-1	Ar_2-10											x			128
Ar_1-1	Ar_2-10												x		129
Ar_1-1	Ar_2-10													x	130
Ar_1-1	Ar_2-11	x													131
Ar_1-1	Ar_2-11		x												132
Ar_1-1	Ar_2-11			x											133

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		Ar$_5$													
Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$-1	Ar$_2$-11				x										134
Ar$_1$-1	Ar$_2$-11					x									135
Ar$_1$-1	Ar$_2$-11						x								136
Ar$_1$-1	Ar$_2$-11							x							137
Ar$_1$-1	Ar$_2$-11								x						138
Ar$_1$-1	Ar$_2$-11									x					139
Ar$_1$-1	Ar$_2$-11										x				140
Ar$_1$-1	Ar$_2$-11											x			141
Ar$_1$-1	Ar$_2$-11												x		142
Ar$_1$-1	Ar$_2$-11													x	143
Ar$_1$-1	Ar$_2$-12	x													144
Ar$_1$-1	Ar$_2$-12		x												145
Ar$_1$-1	Ar$_2$-12			x											146
Ar$_1$-1	Ar$_2$-12				x										147
Ar$_1$-1	Ar$_2$-12					x									148
Ar$_1$-1	Ar$_2$-12						x								149
Ar$_1$-1	Ar$_2$-12							x							150
Ar$_1$-1	Ar$_2$-12								x						151
Ar$_1$-1	Ar$_2$-12									x					152
Ar$_1$-1	Ar$_2$-12										x				153
Ar$_1$-1	Ar$_2$-12											x			154
Ar$_1$-1	Ar$_2$-12												x		155
Ar$_1$-1	Ar$_2$-12													x	156
Ar$_1$-1	Ar$_2$-13	x													157
Ar$_1$-1	Ar$_2$-13		x												158
Ar$_1$-1	Ar$_2$-13			x											159
Ar$_1$-1	Ar$_2$-13				x										160
Ar$_1$-1	Ar$_2$-13					x									161
Ar$_1$-1	Ar$_2$-13						x								162
Ar$_1$-1	Ar$_2$-13							x							163
Ar$_1$-1	Ar$_2$-13								x						164
Ar$_1$-1	Ar$_2$-13									x					165
Ar$_1$-1	Ar$_2$-13										x				166
Ar$_1$-1	Ar$_2$-13											x			167
Ar$_1$-1	Ar$_2$-13												x		168
Ar$_1$-1	Ar$_2$-13													x	169
Ar$_1$-2	Ar$_2$-2	x													170
Ar$_1$-2	Ar$_2$-2		x												171

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-2	Ar_2-2			x											172
Ar_1-2	Ar_2-2				x										173
Ar_1-2	Ar_2-2					x									174
Ar_1-2	Ar_2-2						x								175
Ar_1-2	Ar_2-2							x							176
Ar_1-2	Ar_2-2								x						177
Ar_1-2	Ar_2-2									x					178
Ar_1-2	Ar_2-2										x				179
Ar_1-2	Ar_2-2											x			180
Ar_1-2	Ar_2-2												x		181
Ar_1-2	Ar_2-2													x	182
Ar_1-2	Ar_2-3	x													183
Ar_1-2	Ar_2-3		x												184
Ar_1-2	Ar_2-3			x											185
Ar_1-2	Ar_2-3				x										186
Ar_1-2	Ar_2-3					x									187
Ar_1-2	Ar_2-3						x								188
Ar_1-2	Ar_2-3							x							189
Ar_1-2	Ar_2-3								x						190
Ar_1-2	Ar_2-3									x					191
Ar_1-2	Ar_2-3										x				192
Ar_1-2	Ar_2-3											x			193
Ar_1-2	Ar_2-3												x		194
Ar_1-2	Ar_2-3													x	195
Ar_1-2	Ar_2-4	x													196
Ar_1-2	Ar_2-4		x												197
Ar_1-2	Ar_2-4			x											198
Ar_1-2	Ar_2-4				x										199
Ar_1-2	Ar_2-4					x									200
Ar_1-2	Ar_2-4						x								201
Ar_1-2	Ar_2-4							x							202
Ar_1-2	Ar_2-4								x						203
Ar_1-2	Ar_2-4									x					204
Ar_1-2	Ar_2-4										x				205
Ar_1-2	Ar_2-4											x			206
Ar_1-2	Ar_2-4												x		207
Ar_1-2	Ar_2-4													x	208
Ar_1-2	Ar_2-5	x													209
Ar_1-2	Ar_2-5		x												210
Ar_1-2	Ar_2-5			x											211
Ar_1-2	Ar_2-5				x										212
Ar_1-2	Ar_2-5					x									213
Ar_1-2	Ar_2-5						x								214
Ar_1-2	Ar_2-5							x							215
Ar_1-2	Ar_2-5								x						216
Ar_1-2	Ar_2-5									x					217
Ar_1-2	Ar_2-5										x				218
Ar_1-2	Ar_2-5											x			219
Ar_1-2	Ar_2-5												x		220
Ar_1-2	Ar_2-5													x	221
Ar_1-2	Ar_2-6	x													222
Ar_1-2	Ar_2-6		x												223
Ar_1-2	Ar_2-6			x											224
Ar_1-2	Ar_2-6				x										225
Ar_1-2	Ar_2-6					x									226
Ar_1-2	Ar_2-6						x								227
Ar_1-2	Ar_2-6							x							228
Ar_1-2	Ar_2-6								x						229
Ar_1-2	Ar_2-6									x					230
Ar_1-2	Ar_2-6										x				231
Ar_1-2	Ar_2-6											x			232
Ar_1-2	Ar_2-6												x		233
Ar_1-2	Ar_2-6													x	234
Ar_1-2	Ar_2-7	x													235
Ar_1-2	Ar_2-7		x												236
Ar_1-2	Ar_2-7			x											237
Ar_1-2	Ar_2-7				x										238
Ar_1-2	Ar_2-7					x									239
Ar_1-2	Ar_2-7						x								240
Ar_1-2	Ar_2-7							x							241
Ar_1-2	Ar_2-7								x						242
Ar_1-2	Ar_2-7									x					243
Ar_1-2	Ar_2-7										x				244
Ar_1-2	Ar_2-7											x			245

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-2	Ar_2-7												x		246
Ar_1-2	Ar_2-7													x	247
Ar_1-2	Ar_2-8	x													248
Ar_1-2	Ar_2-8		x												249
Ar_1-2	Ar_2-8			x											250
Ar_1-2	Ar_2-8				x										251
Ar_1-2	Ar_2-8					x									252
Ar_1-2	Ar_2-8						x								253
Ar_1-2	Ar_2-8							x							254
Ar_1-2	Ar_2-8								x						255
Ar_1-2	Ar_2-8									x					256
Ar_1-2	Ar_2-8										x				257
Ar_1-2	Ar_2-8											x			258
Ar_1-2	Ar_2-8												x		259
Ar_1-2	Ar_2-8													x	260
Ar_1-2	Ar_2-9	x													261
Ar_1-2	Ar_2-9		x												262
Ar_1-2	Ar_2-9			x											263
Ar_1-2	Ar_2-9				x										264
Ar_1-2	Ar_2-9					x									265
Ar_1-2	Ar_2-9						x								266
Ar_1-2	Ar_2-9							x							267
Ar_1-2	Ar_2-9								x						268
Ar_1-2	Ar_2-9									x					269
Ar_1-2	Ar_2-9										x				270
Ar_1-2	Ar_2-9											x			271
Ar_1-2	Ar_2-9												x		272
Ar_1-2	Ar_2-9													x	273
Ar_1-2	Ar_2-10	x													274
Ar_1-2	Ar_2-10		x												275
Ar_1-2	Ar_2-10			x											276
Ar_1-2	Ar_2-10				x										277
Ar_1-2	Ar_2-10					x									278
Ar_1-2	Ar_2-10						x								279
Ar_1-2	Ar_2-10							x							280
Ar_1-2	Ar_2-10								x						281
Ar_1-2	Ar_2-10									x					282
Ar_1-2	Ar_2-10										x				283
Ar_1-2	Ar_2-10											x			284
Ar_1-2	Ar_2-10												x		285
Ar_1-2	Ar_2-10													x	286
Ar_1-2	Ar_2-11	x													287
Ar_1-2	Ar_2-11		x												288
Ar_1-2	Ar_2-11			x											289
Ar_1-2	Ar_2-11				x										290
Ar_1-2	Ar_2-11					x									291
Ar_1-2	Ar_2-11						x								292
Ar_1-2	Ar_2-11							x							293
Ar_1-2	Ar_2-11								x						294
Ar_1-2	Ar_2-11									x					295
Ar_1-2	Ar_2-11										x				296

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-2	Ar_2-11											x			297
Ar_1-2	Ar_2-11												x		298
Ar_1-2	Ar_2-11													x	299
Ar_1-2	Ar_2-12	x													300
Ar_1-2	Ar_2-12		x												301
Ar_1-2	Ar_2-12			x											302
Ar_1-2	Ar_2-12				x										303
Ar_1-2	Ar_2-12					x									304
Ar_1-2	Ar_2-12						x								305
Ar_1-2	Ar_2-12							x							306
Ar_1-2	Ar_2-12								x						307
Ar_1-2	Ar_2-12									x					308
Ar_1-2	Ar_2-12										x				309
Ar_1-2	Ar_2-12											x			310
Ar_1-2	Ar_2-12												x		311
Ar_1-2	Ar_2-12													x	312
Ar_1-2	Ar_2-13	x													313
Ar_1-2	Ar_2-13		x												314
Ar_1-2	Ar_2-13			x											315
Ar_1-2	Ar_2-13				x										316
Ar_1-2	Ar_2-13					x									317
Ar_1-2	Ar_2-13						x								318
Ar_1-2	Ar_2-13							x							319
Ar_1-2	Ar_2-13								x						320
Ar_1-2	Ar_2-13									x					321
Ar_1-2	Ar_2-13										x				322
Ar_1-2	Ar_2-13											x			323
Ar_1-2	Ar_2-13												x		324
Ar_1-2	Ar_2-13													x	325
Ar_1-3	Ar_2-3	x													326
Ar_1-3	Ar_2-3		x												327
Ar_1-3	Ar_2-3			x											328
Ar_1-3	Ar_2-3				x										329
Ar_1-3	Ar_2-3					x									330
Ar_1-3	Ar_2-3						x								331
Ar_1-3	Ar_2-3							x							332
Ar_1-3	Ar_2-3								x						333
Ar_1-3	Ar_2-3									x					334
Ar_1-3	Ar_2-3										x				335
Ar_1-3	Ar_2-3											x			336
Ar_1-3	Ar_2-3												x		337
Ar_1-3	Ar_2-3													x	338
Ar_1-3	Ar_2-4	x													339
Ar_1-3	Ar_2-4		x												340
Ar_1-3	Ar_2-4			x											341

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-3	Ar_2-4				x										342
Ar_1-3	Ar_2-4					x									343
Ar_1-3	Ar_2-4						x								344
Ar_1-3	Ar_2-4							x							345
Ar_1-3	Ar_2-4								x						346
Ar_1-3	Ar_2-4									x					347
Ar_1-3	Ar_2-4										x				348
Ar_1-3	Ar_2-4											x			349
Ar_1-3	Ar_2-4												x		350
Ar_1-3	Ar_2-4													x	351
Ar_1-3	Ar_2-5	x													352
Ar_1-3	Ar_2-5		x												353
Ar_1-3	Ar_2-5			x											354
Ar_1-3	Ar_2-5				x										355
Ar_1-3	Ar_2-5					x									356
Ar_1-3	Ar_2-5						x								357
Ar_1-3	Ar_2-5							x							358
Ar_1-3	Ar_2-5								x						359
Ar_1-3	Ar_2-5									x					360
Ar_1-3	Ar_2-5										x				361
Ar_1-3	Ar_2-5											x			362
Ar_1-3	Ar_2-5												x		363
Ar_1-3	Ar_2-5													x	364
Ar_1-3	Ar_2-6	x													365
Ar_1-3	Ar_2-6		x												366
Ar_1-3	Ar_2-6			x											367
Ar_1-3	Ar_2-6				x										368
Ar_1-3	Ar_2-6					x									369
Ar_1-3	Ar_2-6						x								370
Ar_1-3	Ar_2-6							x							371
Ar_1-3	Ar_2-6								x						372
Ar_1-3	Ar_2-6									x					373
Ar_1-3	Ar_2-6										x				374
Ar_1-3	Ar_2-6											x			375
Ar_1-3	Ar_2-6												x		376
Ar_1-3	Ar_2-6													x	377
Ar_1-3	Ar_2-7	x													378
Ar_1-3	Ar_2-7		x												379
Ar_1-3	Ar_2-7			x											380
Ar_1-3	Ar_2-7				x										381
Ar_1-3	Ar_2-7					x									382
Ar_1-3	Ar_2-7						x								383
Ar_1-3	Ar_2-7							x							384
Ar_1-3	Ar_2-7								x						385
Ar_1-3	Ar_2-7									x					386
Ar_1-3	Ar_2-7										x				387
Ar_1-3	Ar_2-7											x			388
Ar_1-3	Ar_2-7												x		389
Ar_1-3	Ar_2-7													x	390
Ar_1-3	Ar_2-8	x													391
Ar_1-3	Ar_2-8		x												392
Ar_1-3	Ar_2-8			x											393
Ar_1-3	Ar_2-8				x										394
Ar_1-3	Ar_2-8					x									395
Ar_1-3	Ar_2-8						x								396
Ar_1-3	Ar_2-8							x							397
Ar_1-3	Ar_2-8								x						398
Ar_1-3	Ar_2-8									x					399
Ar_1-3	Ar_2-8										x				400
Ar_1-3	Ar_2-8											x			401
Ar_1-3	Ar_2-8												x		402
Ar_1-3	Ar_2-8													x	403
Ar_1-3	Ar_2-9	x													404
Ar_1-3	Ar_2-9		x												405
Ar_1-3	Ar_2-9			x											406
Ar_1-3	Ar_2-9				x										407
Ar_1-3	Ar_2-9					x									408
Ar_1-3	Ar_2-9						x								409
Ar_1-3	Ar_2-9							x							410
Ar_1-3	Ar_2-9								x						411
Ar_1-3	Ar_2-9									x					412
Ar_1-3	Ar_2-9										x				413
Ar_1-3	Ar_2-9											x			414
Ar_1-3	Ar_2-9												x		415

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-3	Ar_2-9													x	416
Ar_1-3	Ar_2-10	x													417
Ar_1-3	Ar_2-10		x												418
Ar_1-3	Ar_2-10			x											419
Ar_1-3	Ar_2-10				x										420
Ar_1-3	Ar_2-10					x									421
Ar_1-3	Ar_2-10						x								422
Ar_1-3	Ar_2-10							x							423
Ar_1-3	Ar_2-10								x						424
Ar_1-3	Ar_2-10									x					425
Ar_1-3	Ar_2-10										x				426
Ar_1-3	Ar_2-10											x			427
Ar_1-3	Ar_2-10												x		428
Ar_1-3	Ar_2-10													x	429
Ar_1-3	Ar_2-11	x													430
Ar_1-3	Ar_2-11		x												431
Ar_1-3	Ar_2-11			x											432
Ar_1-3	Ar_2-11				x										433
Ar_1-3	Ar_2-11					x									434
Ar_1-3	Ar_2-11						x								435
Ar_1-3	Ar_2-11							x							436
Ar_1-3	Ar_2-11								x						437
Ar_1-3	Ar_2-11									x					438
Ar_1-3	Ar_2-11										x				439
Ar_1-3	Ar_2-11											x			440
Ar_1-3	Ar_2-11												x		441
Ar_1-3	Ar_2-11													x	442
Ar_1-3	Ar_2-12	x													443
Ar_1-3	Ar_2-12		x												444
Ar_1-3	Ar_2-12			x											445
Ar_1-3	Ar_2-12				x										446
Ar_1-3	Ar_2-12					x									447
Ar_1-3	Ar_2-12						x								448
Ar_1-3	Ar_2-12							x							449
Ar_1-3	Ar_2-12								x						450
Ar_1-3	Ar_2-12									x					451
Ar_1-3	Ar_2-12										x				452

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-3	Ar_2-12											x			453
Ar_1-3	Ar_2-12												x		454
Ar_1-3	Ar_2-12													x	455
Ar_1-3	Ar_2-13	x													456
Ar_1-3	Ar_2-13		x												457
Ar_1-3	Ar_2-13			x											458
Ar_1-3	Ar_2-13				x										459
Ar_1-3	Ar_2-13					x									460
Ar_1-3	Ar_2-13						x								461
Ar_1-3	Ar_2-13							x							462
Ar_1-3	Ar_2-13								x						463
Ar_1-3	Ar_2-13									x					464
Ar_1-3	Ar_2-13										x				465
Ar_1-3	Ar_2-13											x			466
Ar_1-3	Ar_2-13												x		467
Ar_1-3	Ar_2-13													x	468
Ar_1-4	Ar_2-4	x													469
Ar_1-4	Ar_2-4		x												470
Ar_1-4	Ar_2-4			x											471
Ar_1-4	Ar_2-4				x										472
Ar_1-4	Ar_2-4					x									473
Ar_1-4	Ar_2-4						x								474
Ar_1-4	Ar_2-4							x							475
Ar_1-4	Ar_2-4								x						476
Ar_1-4	Ar_2-4									x					477
Ar_1-4	Ar_2-4										x				478
Ar_1-4	Ar_2-4											x			479
Ar_1-4	Ar_2-4												x		480
Ar_1-4	Ar_2-4													x	481
Ar_1-4	Ar_2-5	x													482
Ar_1-4	Ar_2-5		x												483
Ar_1-4	Ar_2-5			x											484
Ar_1-4	Ar_2-5				x										485
Ar_1-4	Ar_2-5					x									486
Ar_1-4	Ar_2-5						x								487
Ar_1-4	Ar_2-5							x							488
Ar_1-4	Ar_2-5								x						489
Ar_1-4	Ar_2-5									x					490
Ar_1-4	Ar_2-5										x				491
Ar_1-4	Ar_2-5											x			492
Ar_1-4	Ar_2-5												x		493
Ar_1-4	Ar_2-5													x	494
Ar_1-4	Ar_2-6	x													495
Ar_1-4	Ar_2-6		x												496
Ar_1-4	Ar_2-6			x											497
Ar_1-4	Ar_2-6				x										498
Ar_1-4	Ar_2-6					x									499
Ar_1-4	Ar_2-6						x								500
Ar_1-4	Ar_2-6							x							501
Ar_1-4	Ar_2-6								x						502
Ar_1-4	Ar_2-6									x					503
Ar_1-4	Ar_2-6										x				504
Ar_1-4	Ar_2-6											x			505
Ar_1-4	Ar_2-6												x		506
Ar_1-4	Ar_2-6													x	507
Ar_1-4	Ar_2-7	x													508
Ar_1-4	Ar_2-7		x												509
Ar_1-4	Ar_2-7			x											510

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-4	Ar_2-7				x										511
Ar_1-4	Ar_2-7					x									512
Ar_1-4	Ar_2-7						x								513
Ar_1-4	Ar_2-7							x							514
Ar_1-4	Ar_2-7								x						515
Ar_1-4	Ar_2-7									x					516
Ar_1-4	Ar_2-7										x				517
Ar_1-4	Ar_2-7											x			518
Ar_1-4	Ar_2-7												x		519
Ar_1-4	Ar_2-7													x	520
Ar_1-4	Ar_2-8	x													521
Ar_1-4	Ar_2-8		x												522
Ar_1-4	Ar_2-8			x											523
Ar_1-4	Ar_2-8				x										524
Ar_1-4	Ar_2-8					x									525
Ar_1-4	Ar_2-8						x								526
Ar_1-4	Ar_2-8							x							527
Ar_1-4	Ar_2-8								x						528
Ar_1-4	Ar_2-8									x					529
Ar_1-4	Ar_2-8										x				530
Ar_1-4	Ar_2-8											x			531
Ar_1-4	Ar_2-8												x		532
Ar_1-4	Ar_2-8													x	533
Ar_1-4	Ar_2-9	x													534
Ar_1-4	Ar_2-9		x												535
Ar_1-4	Ar_2-9			x											536
Ar_1-4	Ar_2-9				x										537
Ar_1-4	Ar_2-9					x									538
Ar_1-4	Ar_2-9						x								539
Ar_1-4	Ar_2-9							x							540
Ar_1-4	Ar_2-9								x						541
Ar_1-4	Ar_2-9									x					542
Ar_1-4	Ar_2-9										x				543
Ar_1-4	Ar_2-9											x			544
Ar_1-4	Ar_2-9												x		545
Ar_1-4	Ar_2-9													x	546
Ar_1-4	Ar_2-10	x													547
Ar_1-4	Ar_2-10		x												548
Ar_1-4	Ar_2-10			x											549
Ar_1-4	Ar_2-10				x										550
Ar_1-4	Ar_2-10					x									551
Ar_1-4	Ar_2-10						x								552
Ar_1-4	Ar_2-10							x							553
Ar_1-4	Ar_2-10								x						554
Ar_1-4	Ar_2-10									x					555
Ar_1-4	Ar_2-10										x				556
Ar_1-4	Ar_2-10											x			557
Ar_1-4	Ar_2-10												x		558
Ar_1-4	Ar_2-10													x	559
Ar_1-4	Ar_2-11	x													560
Ar_1-4	Ar_2-11		x												561
Ar_1-4	Ar_2-11			x											562
Ar_1-4	Ar_2-11				x										563
Ar_1-4	Ar_2-11					x									564
Ar_1-4	Ar_2-11						x								565

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		Ar$_5$													
Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$-4	Ar$_2$-11							x							566
Ar$_1$-4	Ar$_2$-11								x						567
Ar$_1$-4	Ar$_2$-11									x					568
Ar$_1$-4	Ar$_2$-11										x				569
Ar$_1$-4	Ar$_2$-11											x			570
Ar$_1$-4	Ar$_2$-11												x		571
Ar$_1$-4	Ar$_2$-11													x	572
Ar$_1$-4	Ar$_2$-12	x													573
Ar$_1$-4	Ar$_2$-12		x												574
Ar$_1$-4	Ar$_2$-12			x											575
Ar$_1$-4	Ar$_2$-12				x										576
Ar$_1$-4	Ar$_2$-12					x									577
Ar$_1$-4	Ar$_2$-12						x								578
Ar$_1$-4	Ar$_2$-12							x							579
Ar$_1$-4	Ar$_2$-12								x						580
Ar$_1$-4	Ar$_2$-12									x					581
Ar$_1$-4	Ar$_2$-12										x				582
Ar$_1$-4	Ar$_2$-12											x			583
Ar$_1$-4	Ar$_2$-12												x		584
Ar$_1$-4	Ar$_2$-12													x	585
Ar$_1$-4	Ar$_2$-13	x													586
Ar$_1$-4	Ar$_2$-13		x												587
Ar$_1$-4	Ar$_2$-13			x											588
Ar$_1$-4	Ar$_2$-13				x										589
Ar$_1$-4	Ar$_2$-13					x									590
Ar$_1$-4	Ar$_2$-13						x								591
Ar$_1$-4	Ar$_2$-13							x							592
Ar$_1$-4	Ar$_2$-13								x						593
Ar$_1$-4	Ar$_2$-13									x					594
Ar$_1$-4	Ar$_2$-13										x				595
Ar$_1$-4	Ar$_2$-13											x			596
Ar$_1$-4	Ar$_2$-13												x		597
Ar$_1$-4	Ar$_2$-13													x	598
Ar$_1$-5	Ar$_2$-5	x													599
Ar$_1$-5	Ar$_2$-5		x												600
Ar$_1$-5	Ar$_2$-5			x											601
Ar$_1$-5	Ar$_2$-5				x										602
Ar$_1$-5	Ar$_2$-5					x									603
Ar$_1$-5	Ar$_2$-5						x								604
Ar$_1$-5	Ar$_2$-5							x							605
Ar$_1$-5	Ar$_2$-5								x						606

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-5	Ar_2-5									x					607
Ar_1-5	Ar_2-5										x				608
Ar_1-5	Ar_2-5											x			609
Ar_1-5	Ar_2-5												x		610
Ar_1-5	Ar_2-5													x	611
Ar_1-5	Ar_2-6	x													612
Ar_1-5	Ar_2-6		x												613
Ar_1-5	Ar_2-6			x											614
Ar_1-5	Ar_2-6				x										615
Ar_1-5	Ar_2-6					x									616
Ar_1-5	Ar_2-6						x								617
Ar_1-5	Ar_2-6							x							618
Ar_1-5	Ar_2-6								x						619
Ar_1-5	Ar_2-6									x					620
Ar_1-5	Ar_2-6										x				621
Ar_1-5	Ar_2-6											x			622
Ar_1-5	Ar_2-6												x		623
Ar_1-5	Ar_2-6													x	624
Ar_1-5	Ar_2-7	x													625
Ar_1-5	Ar_2-7		x												626
Ar_1-5	Ar_2-7			x											627
Ar_1-5	Ar_2-7				x										628
Ar_1-5	Ar_2-7					x									629
Ar_1-5	Ar_2-7						x								630
Ar_1-5	Ar_2-7							x							631
Ar_1-5	Ar_2-7								x						632
Ar_1-5	Ar_2-7									x					633
Ar_1-5	Ar_2-7										x				634
Ar_1-5	Ar_2-7											x			635
Ar_1-5	Ar_2-7												x		636
Ar_1-5	Ar_2-7													x	637
Ar_1-5	Ar_2-8	x													638
Ar_1-5	Ar_2-8		x												639
Ar_1-5	Ar_2-8			x											640
Ar_1-5	Ar_2-8				x										641
Ar_1-5	Ar_2-8					x									642
Ar_1-5	Ar_2-8						x								643
Ar_1-5	Ar_2-8							x							644
Ar_1-5	Ar_2-8								x						645
Ar_1-5	Ar_2-8									x					646
Ar_1-5	Ar_2-8										x				647
Ar_1-5	Ar_2-8											x			648
Ar_1-5	Ar_2-8												x		649
Ar_1-5	Ar_2-8													x	650
Ar_1-5	Ar_2-9	x													651
Ar_1-5	Ar_2-9		x												652
Ar_1-5	Ar_2-9			x											653
Ar_1-5	Ar_2-9				x										654
Ar_1-5	Ar_2-9					x									655
Ar_1-5	Ar_2-9						x								656
Ar_1-5	Ar_2-9							x							657
Ar_1-5	Ar_2-9								x						658
Ar_1-5	Ar_2-9									x					659
Ar_1-5	Ar_2-9										x				660
Ar_1-5	Ar_2-9											x			661
Ar_1-5	Ar_2-9												x		662
Ar_1-5	Ar_2-9													x	663
Ar_1-5	Ar_2-10	x													664
Ar_1-5	Ar_2-10		x												665
Ar_1-5	Ar_2-10			x											666
Ar_1-5	Ar_2-10				x										667
Ar_1-5	Ar_2-10					x									668
Ar_1-5	Ar_2-10						x								669
Ar_1-5	Ar_2-10							x							670
Ar_1-5	Ar_2-10								x						671

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		Ar$_5$													
Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$-5	Ar$_2$-10									x					672
Ar$_1$-5	Ar$_2$-10										x				673
Ar$_1$-5	Ar$_2$-10											x			674
Ar$_1$-5	Ar$_2$-10												x		675
Ar$_1$-5	Ar$_2$-10													x	676
Ar$_1$-5	Ar$_2$-11	x													677
Ar$_1$-5	Ar$_2$-11		x												678
Ar$_1$-5	Ar$_2$-11			x											679
Ar$_1$-5	Ar$_2$-11				x										680
Ar$_1$-5	Ar$_2$-11					x									681
Ar$_1$-5	Ar$_2$-11						x								682
Ar$_1$-5	Ar$_2$-11							x							683
Ar$_1$-5	Ar$_2$-11								x						684
Ar$_1$-5	Ar$_2$-11									x					685
Ar$_1$-5	Ar$_2$-11										x				686
Ar$_1$-5	Ar$_2$-11											x			687
Ar$_1$-5	Ar$_2$-11												x		688
Ar$_1$-5	Ar$_2$-11													x	689
Ar$_1$-5	Ar$_2$-12	x													690
Ar$_1$-5	Ar$_2$-12		x												691
Ar$_1$-5	Ar$_2$-12			x											692
Ar$_1$-5	Ar$_2$-12				x										693
Ar$_1$-5	Ar$_2$-12					x									694
Ar$_1$-5	Ar$_2$-12						x								695
Ar$_1$-5	Ar$_2$-12							x							696
Ar$_1$-5	Ar$_2$-12								x						697
Ar$_1$-5	Ar$_2$-12									x					698
Ar$_1$-5	Ar$_2$-12										x				699
Ar$_1$-5	Ar$_2$-12											x			700
Ar$_1$-5	Ar$_2$-12												x		701
Ar$_1$-5	Ar$_2$-12													x	702
Ar$_1$-5	Ar$_2$-13	x													703
Ar$_1$-5	Ar$_2$-13		x												704
Ar$_1$-5	Ar$_2$-13			x											705
Ar$_1$-5	Ar$_2$-13				x										706
Ar$_1$-5	Ar$_2$-13					x									707
Ar$_1$-5	Ar$_2$-13						x								708

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		Ar$_5$													
Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$-5	Ar$_2$-13							x							709
Ar$_1$-5	Ar$_2$-13								x						710
Ar$_1$-5	Ar$_2$-13									x					711
Ar$_1$-5	Ar$_2$-13										x				712
Ar$_1$-5	Ar$_2$-13											x			713
Ar$_1$-5	Ar$_2$-13												x		714
Ar$_1$-5	Ar$_2$-13													x	715
Ar$_1$-6	Ar$_2$-6	x													716
Ar$_1$-6	Ar$_2$-6		x												717
Ar$_1$-6	Ar$_2$-6			x											718
Ar$_1$-6	Ar$_2$-6				x										719
Ar$_1$-6	Ar$_2$-6					x									720
Ar$_1$-6	Ar$_2$-6						x								721
Ar$_1$-6	Ar$_2$-6							x							722
Ar$_1$-6	Ar$_2$-6								x						723
Ar$_1$-6	Ar$_2$-6									x					724
Ar$_1$-6	Ar$_2$-6										x				725
Ar$_1$-6	Ar$_2$-6											x			726
Ar$_1$-6	Ar$_2$-6												x		727
Ar$_1$-6	Ar$_2$-6													x	728
Ar$_1$-6	Ar$_2$-7	x													729
Ar$_1$-6	Ar$_2$-7		x												730
Ar$_1$-6	Ar$_2$-7			x											731
Ar$_1$-6	Ar$_2$-7				x										732
Ar$_1$-6	Ar$_2$-7					x									733
Ar$_1$-6	Ar$_2$-7						x								734
Ar$_1$-6	Ar$_2$-7							x							735
Ar$_1$-6	Ar$_2$-7								x						736
Ar$_1$-6	Ar$_2$-7									x					737
Ar$_1$-6	Ar$_2$-7										x				738
Ar$_1$-6	Ar$_2$-7											x			739
Ar$_1$-6	Ar$_2$-7												x		740
Ar$_1$-6	Ar$_2$-7													x	741
Ar$_1$-6	Ar$_2$-8	x													742
Ar$_1$-6	Ar$_2$-8		x												743
Ar$_1$-6	Ar$_2$-8			x											744
Ar$_1$-6	Ar$_2$-8				x										745
Ar$_1$-6	Ar$_2$-8					x									746
Ar$_1$-6	Ar$_2$-8						x								747
Ar$_1$-6	Ar$_2$-8							x							748
Ar$_1$-6	Ar$_2$-8								x						749
Ar$_1$-6	Ar$_2$-8									x					750
Ar$_1$-6	Ar$_2$-8										x				751
Ar$_1$-6	Ar$_2$-8											x			752
Ar$_1$-6	Ar$_2$-8												x		753
Ar$_1$-6	Ar$_2$-8													x	754
Ar$_1$-6	Ar$_2$-9	x													755
Ar$_1$-6	Ar$_2$-9		x												756
Ar$_1$-6	Ar$_2$-9			x											757
Ar$_1$-6	Ar$_2$-9				x										758
Ar$_1$-6	Ar$_2$-9					x									759
Ar$_1$-6	Ar$_2$-9						x								760
Ar$_1$-6	Ar$_2$-9							x							761
Ar$_1$-6	Ar$_2$-9								x						762
Ar$_1$-6	Ar$_2$-9									x					763
Ar$_1$-6	Ar$_2$-9										x				764
Ar$_1$-6	Ar$_2$-9											x			765
Ar$_1$-6	Ar$_2$-9												x		766
Ar$_1$-6	Ar$_2$-9													x	767
Ar$_1$-6	Ar$_2$-10	x													768
Ar$_1$-6	Ar$_2$-10		x												769
Ar$_1$-6	Ar$_2$-10			x											770
Ar$_1$-6	Ar$_2$-10				x										771

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-6	Ar_2-10					x									772
Ar_1-6	Ar_2-10						x								773
Ar_1-6	Ar_2-10							x							774
Ar_1-6	Ar_2-10								x						775
Ar_1-6	Ar_2-10									x					776
Ar_1-6	Ar_2-10										x				777
Ar_1-6	Ar_2-10											x			778
Ar_1-6	Ar_2-10												x		779
Ar_1-6	Ar_2-10													x	780
Ar_1-6	Ar_2-11	x													781
Ar_1-6	Ar_2-11		x												782
Ar_1-6	Ar_2-11			x											783
Ar_1-6	Ar_2-11				x										784
Ar_1-6	Ar_2-11					x									785
Ar_1-6	Ar_2-11						x								786
Ar_1-6	Ar_2-11							x							787
Ar_1-6	Ar_2-11								x						788
Ar_1-6	Ar_2-11									x					789
Ar_1-6	Ar_2-11										x				790
Ar_1-6	Ar_2-11											x			791
Ar_1-6	Ar_2-11												x		792
Ar_1-6	Ar_2-11													x	793
Ar_1-6	Ar_2-12	x													794
Ar_1-6	Ar_2-12		x												795
Ar_1-6	Ar_2-12			x											796
Ar_1-6	Ar_2-12				x										797
Ar_1-6	Ar_2-12					x									798
Ar_1-6	Ar_2-12						x								799
Ar_1-6	Ar_2-12							x							800
Ar_1-6	Ar_2-12								x						801
Ar_1-6	Ar_2-12									x					802
Ar_1-6	Ar_2-12										x				803
Ar_1-6	Ar_2-12											x			804
Ar_1-6	Ar_2-12												x		805
Ar_1-6	Ar_2-12													x	806
Ar_1-6	Ar_2-13	x													807
Ar_1-6	Ar_2-13		x												808

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-6	Ar_2-13			x											809
Ar_1-6	Ar_2-13				x										810
Ar_1-6	Ar_2-13					x									811
Ar_1-6	Ar_2-13						x								812
Ar_1-6	Ar_2-13							x							813
Ar_1-6	Ar_2-13								x						814
Ar_1-6	Ar_2-13									x					815
Ar_1-6	Ar_2-13										x				816
Ar_1-6	Ar_2-13											x			817
Ar_1-6	Ar_2-13												x		818
Ar_1-6	Ar_2-13													x	819
Ar_1-7	Ar_2-7	x													820
Ar_1-7	Ar_2-7		x												821
Ar_1-7	Ar_2-7			x											822
Ar_1-7	Ar_2-7				x										823
Ar_1-7	Ar_2-7					x									824
Ar_1-7	Ar_2-7						x								825
Ar_1-7	Ar_2-7							x							826
Ar_1-7	Ar_2-7								x						827
Ar_1-7	Ar_2-7									x					828
Ar_1-7	Ar_2-7										x				829
Ar_1-7	Ar_2-7											x			830
Ar_1-7	Ar_2-7												x		831
Ar_1-7	Ar_2-7													x	832
Ar_1-7	Ar_2-8	x													833
Ar_1-7	Ar_2-8		x												834
Ar_1-7	Ar_2-8			x											835
Ar_1-7	Ar_2-8				x										836
Ar_1-7	Ar_2-8					x									837
Ar_1-7	Ar_2-8						x								838
Ar_1-7	Ar_2-8							x							839
Ar_1-7	Ar_2-8								x						840
Ar_1-7	Ar_2-8									x					841
Ar_1-7	Ar_2-8										x				842
Ar_1-7	Ar_2-8											x			843
Ar_1-7	Ar_2-8												x		844
Ar_1-7	Ar_2-8													x	845
Ar_1-7	Ar_2-9	x													846
Ar_1-7	Ar_2-9		x												847
Ar_1-7	Ar_2-9			x											848
Ar_1-7	Ar_2-9				x										849
Ar_1-7	Ar_2-9					x									850
Ar_1-7	Ar_2-9						x								851
Ar_1-7	Ar_2-9							x							852
Ar_1-7	Ar_2-9								x						853
Ar_1-7	Ar_2-9									x					854
Ar_1-7	Ar_2-9										x				855
Ar_1-7	Ar_2-9											x			856
Ar_1-7	Ar_2-9												x		857
Ar_1-7	Ar_2-9													x	858
Ar_1-7	Ar_2-10	x													859
Ar_1-7	Ar_2-10		x												860
Ar_1-7	Ar_2-10			x											861
Ar_1-7	Ar_2-10				x										862
Ar_1-7	Ar_2-10					x									863
Ar_1-7	Ar_2-10						x								864

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		Ar$_5$													
Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$-7	Ar$_2$-10							x							865
Ar$_1$-7	Ar$_2$-10								x						866
Ar$_1$-7	Ar$_2$-10									x					867
Ar$_1$-7	Ar$_2$-10										x				868
Ar$_1$-7	Ar$_2$-10											x			869
Ar$_1$-7	Ar$_2$-10												x		870
Ar$_1$-7	Ar$_2$-10													x	871
Ar$_1$-7	Ar$_2$-11	x													872
Ar$_1$-7	Ar$_2$-11		x												873
Ar$_1$-7	Ar$_2$-11			x											874
Ar$_1$-7	Ar$_2$-11				x										875
Ar$_1$-7	Ar$_2$-11					x									876
Ar$_1$-7	Ar$_2$-11						x								877
Ar$_1$-7	Ar$_2$-11							x							878
Ar$_1$-7	Ar$_2$-11								x						879
Ar$_1$-7	Ar$_2$-11									x					880
Ar$_1$-7	Ar$_2$-11										x				881
Ar$_1$-7	Ar$_2$-11											x			882
Ar$_1$-7	Ar$_2$-11												x		883
Ar$_1$-7	Ar$_2$-11													x	884
Ar$_1$-7	Ar$_2$-12	x													885
Ar$_1$-7	Ar$_2$-12		x												886
Ar$_1$-7	Ar$_2$-12			x											887
Ar$_1$-7	Ar$_2$-12				x										888
Ar$_1$-7	Ar$_2$-12					x									889
Ar$_1$-7	Ar$_2$-12						x								890
Ar$_1$-7	Ar$_2$-12							x							891
Ar$_1$-7	Ar$_2$-12								x						892
Ar$_1$-7	Ar$_2$-12									x					893
Ar$_1$-7	Ar$_2$-12										x				894
Ar$_1$-7	Ar$_2$-12											x			895
Ar$_1$-7	Ar$_2$-12												x		896
Ar$_1$-7	Ar$_2$-12													x	897
Ar$_1$-7	Ar$_2$-13	x													898
Ar$_1$-7	Ar$_2$-13		x												899
Ar$_1$-7	Ar$_2$-13			x											900
Ar$_1$-7	Ar$_2$-13				x										901

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		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-7	Ar_2-13					x									902
Ar_1-7	Ar_2-13						x								903
Ar_1-7	Ar_2-13							x							904
Ar_1-7	Ar_2-13								x						905
Ar_1-7	Ar_2-13									x					906
Ar_1-7	Ar_2-13										x				907
Ar_1-7	Ar_2-13											x			908
Ar_1-7	Ar_2-13												x		909
Ar_1-7	Ar_2-13													x	910
Ar_1-8	Ar_2-8	x													911
Ar_1-8	Ar_2-8		x												912
Ar_1-8	Ar_2-8			x											913
Ar_1-8	Ar_2-8				x										914
Ar_1-8	Ar_2-8					x									915
Ar_1-8	Ar_2-8						x								916
Ar_1-8	Ar_2-8							x							917
Ar_1-8	Ar_2-8								x						918
Ar_1-8	Ar_2-8									x					919
Ar_1-8	Ar_2-8										x				920
Ar_1-8	Ar_2-8											x			921
Ar_1-8	Ar_2-8												x		922
Ar_1-8	Ar_2-8													x	923
Ar_1-8	Ar_2-9	x													924
Ar_1-8	Ar_2-9		x												925
Ar_1-8	Ar_2-9			x											926
Ar_1-8	Ar_2-9				x										927
Ar_1-8	Ar_2-9					x									928
Ar_1-8	Ar_2-9						x								929
Ar_1-8	Ar_2-9							x							930
Ar_1-8	Ar_2-9								x						931
Ar_1-8	Ar_2-9									x					932
Ar_1-8	Ar_2-9										x				933
Ar_1-8	Ar_2-9											x			934
Ar_1-8	Ar_2-9												x		935
Ar_1-8	Ar_2-9													x	936
Ar_1-8	Ar_2-10	x													937
Ar_1-8	Ar_2-10		x												938
Ar_1-8	Ar_2-10			x											939
Ar_1-8	Ar_2-10				x										940
Ar_1-8	Ar_2-10					x									941
Ar_1-8	Ar_2-10						x								942
Ar_1-8	Ar_2-10							x							943
Ar_1-8	Ar_2-10								x						944
Ar_1-8	Ar_2-10									x					945
Ar_1-8	Ar_2-10										x				946
Ar_1-8	Ar_2-10											x			947
Ar_1-8	Ar_2-10												x		948
Ar_1-8	Ar_2-10													x	949
Ar_1-8	Ar_2-11	x													950
Ar_1-8	Ar_2-11		x												951

-continued

		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
Ar_1-8	Ar_2-11			x											952
Ar_1-8	Ar_2-11				x										953
Ar_1-8	Ar_2-11					x									954
Ar_1-8	Ar_2-11						x								955
Ar_1-8	Ar_2-11							x							956
Ar_1-8	Ar_2-11								x						957
Ar_1-8	Ar_2-11									x					958
Ar_1-8	Ar_2-11										x				959
Ar_1-8	Ar_2-11											x			960
Ar_1-8	Ar_2-11												x		961
Ar_1-8	Ar_2-11													x	962
Ar_1-8	Ar_2-12	x													963
Ar_1-8	Ar_2-12		x												964
Ar_1-8	Ar_2-12			x											965
Ar_1-8	Ar_2-12				x										966
Ar_1-8	Ar_2-12					x									967
Ar_1-8	Ar_2-12						x								968
Ar_1-8	Ar_2-12							x							969
Ar_1-8	Ar_2-12								x						970
Ar_1-8	Ar_2-12									x					971
Ar_1-8	Ar_2-12										x				972
Ar_1-8	Ar_2-12											x			973
Ar_1-8	Ar_2-12												x		974
Ar_1-8	Ar_2-12													x	975
Ar_1-8	Ar_2-13	x													976
Ar_1-8	Ar_2-13		x												977
Ar_1-8	Ar_2-13			x											978
Ar_1-8	Ar_2-13				x										979
Ar_1-8	Ar_2-13					x									980
Ar_1-8	Ar_2-13						x								981
Ar_1-8	Ar_2-13							x							982
Ar_1-8	Ar_2-13								x						983
Ar_1-8	Ar_2-13									x					984
Ar_1-8	Ar_2-13										x				985
Ar_1-8	Ar_2-13											x			986
Ar_1-8	Ar_2-13												x		987
Ar_1-8	Ar_2-13													x	988

-continued

		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
$Ar_1$9	Ar_2-9	x													989
$Ar_1$9	Ar_2-9		x												990
$Ar_1$9	Ar_2-9			x											991
$Ar_1$9	Ar_2-9				x										992
$Ar_1$9	Ar_2-9					x									993
$Ar_1$9	Ar_2-9						x								994
$Ar_1$9	Ar_2-9							x							995
$Ar_1$9	Ar_2-9								x						996
$Ar_1$9	Ar_2-9									x					997
$Ar_1$9	Ar_2-9										x				998
$Ar_1$9	Ar_2-9											x			999
$Ar_1$9	Ar_2-9												x		1000
$Ar_1$9	Ar_2-9													x	1001
$Ar_1$9	Ar_2-10	x													1002
$Ar_1$9	Ar_2-10		x												1003
$Ar_1$9	Ar_2-10			x											1004
$Ar_1$9	Ar_2-10				x										1005
$Ar_1$9	Ar_2-10					x									1006
$Ar_1$9	Ar_2-10						x								1007
$Ar_1$9	Ar_2-10							x							1008
$Ar_1$9	Ar_2-10								x						1009
$Ar_1$9	Ar_2-10									x					1010
$Ar_1$9	Ar_2-10										x				1011
$Ar_1$9	Ar_2-10											x			1012
$Ar_1$9	Ar_2-10												x		1013
$Ar_1$9	Ar_2-10													x	1014
$Ar_1$9	Ar_2-11	x													1015
$Ar_1$9	Ar_2-11		x												1016
$Ar_1$9	Ar_2-11			x											1017
$Ar_1$9	Ar_2-11				x										1018
$Ar_1$9	Ar_2-11					x									1019
$Ar_1$9	Ar_2-11						x								1020
$Ar_1$9	Ar_2-11							x							1021
$Ar_1$9	Ar_2-11								x						1022
$Ar_1$9	Ar_2-11									x					1023
$Ar_1$9	Ar_2-11										x				1024
$Ar_1$9	Ar_2-11											x			1025
$Ar_1$9	Ar_2-11												x		1026
$Ar_1$9	Ar_2-11													x	1027
$Ar_1$9	Ar_2-12	x													1028
$Ar_1$9	Ar_2-12		x												1029
$Ar_1$9	Ar_2-12			x											1030
$Ar_1$9	Ar_2-12				x										1031

-continued

Ar$_1$	Ar$_2$	Ar$_5$-1	Ar$_5$-2	Ar$_5$-3	Ar$_5$-4	Ar$_5$-5	Ar$_5$-6	Ar$_5$-7	Ar$_5$-8	Ar$_5$-9	Ar$_5$-10	Ar$_5$-11	Ar$_5$-12	Ar$_5$-13	Compound
Ar$_1$9	Ar$_2$-12					x									1032
Ar$_1$9	Ar$_2$-12						x								1033
Ar$_1$9	Ar$_2$-12							x							1034
Ar$_1$9	Ar$_2$-12								x						1035
Ar$_1$9	Ar$_2$-12									x					1036
Ar$_1$9	Ar$_2$-12										x				1037
Ar$_1$9	Ar$_2$-12											x			1038
Ar$_1$9	Ar$_2$-12												x		1039
Ar$_1$9	Ar$_2$-12													x	1040
Ar$_1$9	Ar$_2$-13	x													1041
Ar$_1$9	Ar$_2$-13		x												1042
Ar$_1$9	Ar$_2$-13			x											1043
Ar$_1$9	Ar$_2$-13				x										1044
Ar$_1$9	Ar$_2$-13					x									1045
Ar$_1$9	Ar$_2$-13						x								1046
Ar$_1$9	Ar$_2$-13							x							1047
Ar$_1$9	Ar$_2$-13								x						1048
Ar$_1$9	Ar$_2$-13									x					1049
Ar$_1$9	Ar$_2$-13										x				1050
Ar$_1$9	Ar$_2$-13											x			1051
Ar$_1$9	Ar$_2$-13												x		1052
Ar$_1$9	Ar$_2$-13													x	1053
Ar$_1$10	Ar$_2$-10	x													1054
Ar$_1$10	Ar$_2$-10		x												1055
Ar$_1$10	Ar$_2$-10			x											1056
Ar$_1$10	Ar$_2$-10				x										1057
Ar$_1$10	Ar$_2$-10					x									1058
Ar$_1$10	Ar$_2$-10						x								1059
Ar$_1$10	Ar$_2$-10							x							1060
Ar$_1$10	Ar$_2$-10								x						1061
Ar$_1$10	Ar$_2$-10									x					1062
Ar$_1$10	Ar$_2$-10										x				1063
Ar$_1$10	Ar$_2$-10											x			1064
Ar$_1$10	Ar$_2$-10												x		1065
Ar$_1$10	Ar$_2$-10													x	1066
Ar$_1$10	Ar$_2$-11	x													1067
Ar$_1$10	Ar$_2$-11		x												1068

-continued

		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
$Ar_1$10	Ar_2-11			x											1069
$Ar_1$10	Ar_2-11				x										1070
$Ar_1$10	Ar_2-11					x									1071
$Ar_1$10	Ar_2-11						x								1072
$Ar_1$10	Ar_2-11							x							1073
$Ar_1$10	Ar_2-11								x						1074
$Ar_1$10	Ar_2-11									x					1075
$Ar_1$10	Ar_2-11										x				1076
$Ar_1$10	Ar_2-11											x			1077
$Ar_1$10	Ar_2-11												x		1078
$Ar_1$10	Ar_2-11													x	1079
$Ar_1$10	Ar_2-12	x													1080
$Ar_1$10	Ar_2-12		x												1081
$Ar_1$10	Ar_2-12			x											1082
$Ar_1$10	Ar_2-12				x										1083
$Ar_1$10	Ar_2-12					x									1084
$Ar_1$10	Ar_2-12						x								1085
$Ar_1$10	Ar_2-12							x							1086
$Ar_1$10	Ar_2-12								x						1087
$Ar_1$10	Ar_2-12									x					1088
$Ar_1$10	Ar_2-12										x				1089
$Ar_1$10	Ar_2-12											x			1090
$Ar_1$10	Ar_2-12												x		1091
$Ar_1$10	Ar_2-12													x	1092
$Ar_1$10	Ar_2-13	x													1093
$Ar_1$10	Ar_2-13		x												1094
$Ar_1$10	Ar_2-13			x											1095
$Ar_1$10	Ar_2-13				x										1096
$Ar_1$10	Ar_2-13					x									1097
$Ar_1$10	Ar_2-13						x								1098
$Ar_1$10	Ar_2-13							x							1099
$Ar_1$10	Ar_2-13								x						1100
$Ar_1$10	Ar_2-13									x					1101
$Ar_1$10	Ar_2-13										x				1102
$Ar_1$10	Ar_2-13											x			1103
$Ar_1$10	Ar_2-13												x		1104
$Ar_1$10	Ar_2-13													x	1105

-continued

		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
$Ar_1$11	Ar_2-11	x													1106
$Ar_1$11	Ar_2-11		x												1107
$Ar_1$11	Ar_2-11			x											1108
$Ar_1$11	Ar_2-11				x										1109
$Ar_1$11	Ar_2-11					x									1110
$Ar_1$11	Ar_2-11						x								1111
$Ar_1$11	Ar_2-11							x							1112
$Ar_1$11	Ar_2-11								x						1113
$Ar_1$11	Ar_2-11									x					1114
$Ar_1$11	Ar_2-11										x				1115
$Ar_1$11	Ar_2-11											x			1116
$Ar_1$11	Ar_2-11												x		1117
$Ar_1$11	Ar_2-11													x	1118
$Ar_1$11	Ar_2-12	x													1119
$Ar_1$11	Ar_2-12		x												1120
$Ar_1$11	Ar_2-12			x											1121
$Ar_1$11	Ar_2-12				x										1122
$Ar_1$11	Ar_2-12					x									1123
$Ar_1$11	Ar_2-12						x								1124
$Ar_1$11	Ar_2-12							x							1125
$Ar_1$11	Ar_2-12								x						1126
$Ar_1$11	Ar_2-12									x					1127
$Ar_1$11	Ar_2-12										x				1128
$Ar_1$11	Ar_2-12											x			1129
$Ar_1$11	Ar_2-12												x		1130
$Ar_1$11	Ar_2-12													x	1131
$Ar_1$11	Ar_2-13	x													1132
$Ar_1$11	Ar_2-13		x												1133
$Ar_1$11	Ar_2-13			x											1134
$Ar_1$11	Ar_2-13				x										1135
$Ar_1$11	Ar_2-13					x									1136
$Ar_1$11	Ar_2-13						x								1137
$Ar_1$11	Ar_2-13							x							1138
$Ar_1$11	Ar_2-13								x						1139
$Ar_1$11	Ar_2-13									x					1140
$Ar_1$11	Ar_2-13										x				1141
$Ar_1$11	Ar_2-13											x			1142

-continued

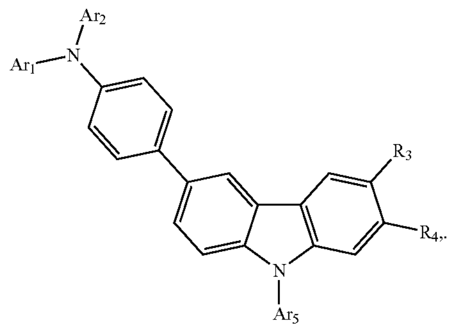
		Ar_5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
$Ar_1$11	Ar_2-13												x		1143
$Ar_1$11	Ar_2-13													x	1144
$Ar_1$12	Ar_2-12	x													1145
$Ar_1$12	Ar_2-12		x												1146
$Ar_1$12	Ar_2-12			x											1147
$Ar_1$12	Ar_2-12				x										1148
$Ar_1$12	Ar_2-12					x									1149
$Ar_1$12	Ar_2-12						x								1150
$Ar_1$12	Ar_2-12							x							1151
$Ar_1$12	Ar_2-12								x						1152
$Ar_1$12	Ar_2-12									x					1153
$Ar_1$12	Ar_2-12										x				1154
$Ar_1$12	Ar_2-12											x			1155
$Ar_1$12	Ar_2-12												x		1156
$Ar_1$12	Ar_2-12													x	1157
$Ar_1$12	Ar_2-13	x													1158
$Ar_1$12	Ar_2-13		x												1159
$Ar_1$12	Ar_2-13			x											1160
$Ar_1$12	Ar_2-13				x										1161
$Ar_1$12	Ar_2-13					x									1162
$Ar_1$12	Ar_2-13						x								1163
$Ar_1$12	Ar_2-13							x							1164
$Ar_1$12	Ar_2-13								x						1165
$Ar_1$12	Ar_2-13									x					1166
$Ar_1$12	Ar_2-13										x				1167
$Ar_1$12	Ar_2-13											x			1168
$Ar_1$12	Ar_2-13												x		1169
$Ar_1$12	Ar_2-13													x	1170
$Ar_1$13	Ar_2-13	x													1171
$Ar_1$13	Ar_2-13		x												1172
$Ar_1$13	Ar_2-13			x											1173
$Ar_1$13	Ar_2-13				x										1174
$Ar_1$13	Ar_2-13					x									1175
$Ar_1$13	Ar_2-13						x								1176
$Ar_1$13	Ar_2-13							x							1177
$Ar_1$13	Ar_2-13								x						1178
$Ar_1$13	Ar_2-13									x					1179

-continued

		Ar5													
Ar_1	Ar_2	Ar_5-1	Ar_5-2	Ar_5-3	Ar_5-4	Ar_5-5	Ar_5-6	Ar_5-7	Ar_5-8	Ar_5-9	Ar_5-10	Ar_5-11	Ar_5-12	Ar_5-13	Compound
$Ar_1$13	Ar_2-13										x				1180
$Ar_1$13	Ar_2-13											x			1181
$Ar_1$13	Ar_2-13												x		1182
$Ar_1$13	Ar_2-13													x	1183

In one embodiment, a first device is provided. The first device comprises an organic light emitting device, further comprising: an anode, a cathode, a hole injection layer disposed between the anode and the emissive layer, a first hole transport layer disposed between the hole injection layer and the emissive layer, and a second hole transport layer disposed between the first hole transport layer and the emissive layer, and wherein the second hole transport layer comprises a compound of formula:

Formula II



In the compound of Formula II, Ar_1, Ar_2, and Ar_5 are independently selected from the group consisting of aryl and heteroaryl and R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfanyl, sulfonyl, phosphino, and combinations thereof.

As used herein, a hole transporting layer (HTL) in an OLED can be disposed between the and anode and the emissive layer. It is preferred that the HTL is relatively hole conductive, which helps avoid high operating voltage. In order to achieve high hole conductivity, high hole mobility materials are used. These materials are usually triarylamine compounds. These compounds may have HOMO/LUMO levels and/or triplet energy which are not compatible with the emissive layer for optimum device performance and lifetime. On the other hand, in order to have an HTL with more compatible HOMO/LUMO levels and/or triplet energy, hole mobility may be compromised.

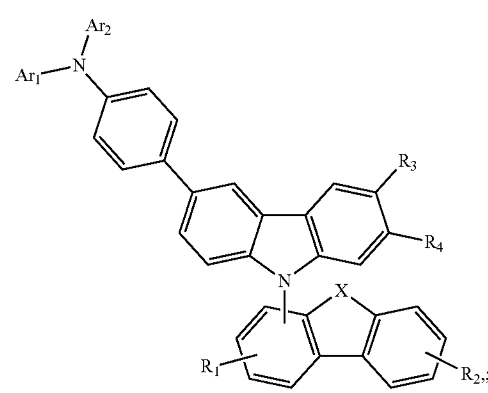
In order to achieve a low voltage, higher device performance and lifetime device, the introduction of a secondary hole transporting layer, in addition to the primary hole transporting layer has been demonstrated and shown to be effective. The primary hole transporting layer is largely responsible for hole transport. The secondary hole transporting layer, sandwiched between the primary hole transporting layer and the emissive layer, functions as a bridging layer. The thickness of the secondary hole transport layer is preferably low in order to not significantly increase the operating voltage. However, the hole injection from the secondary hole transporting layer to the emissive layer, charge confinement and excition confinement between the secondary hole transporting layer and the emissive layer are controlled by the energy levels and single/triplet energy of the secondary hole transporting layer. Since the secondary hole transporting layer thickness is low, there is relatively little concern about the hole mobility. This allows for a higher flexibility in the design of materials with appropriate energy levels and single/triplet energy to function well with the emissive layer.

It has surprisingly been discovered that compounds of Formula I and Formula II are useful materials in the secondary hole transporting layer. In the compounds of Formula I, the most electron rich portion of the molecule is the $N(Ar_1)(Ar_2)$ group. Without being bound by theory, this part is believed to be mostly responsible for the hole transport.

The carbazole-N—Ar_5 moiety may be less electron rich and may provide a relatively accessible LUMO level and π-conjugation to stabilize radical anions if the material is reduced. In particular, Ar_5 is preferably a high triplet fused-ring aromatic as disclosed herein. In some embodiments, Ar_5 can be triphenylene or heteroaromatic group such as dibenzofuran, dibenzothiophene and dibenzoselenophene. It has been discovered that the aforementioned substitution pattern for Ar_1, Ar_2, and Ar_5 can render compounds with high triplet energy and significant charge stabilization.

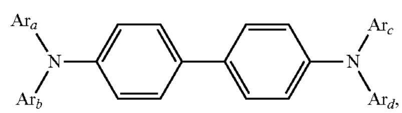
In one embodiment, the compound has the formula:

Formula I



wherein X is selected from the group consisting of O, S, and Se, wherein R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and wherein R_1 and R_2 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

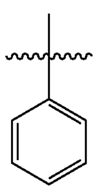
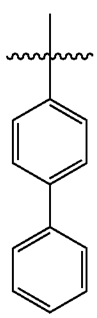
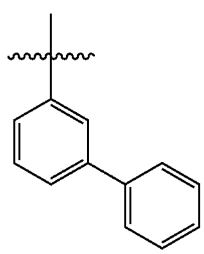
In one embodiment, the second hole transport layer is disposed adjacent to the first hole transport layer. By "adjacent" it is meant that the second hole transport layer is physically in contact with the first hole transport layer. In one embodiment, the first hole transport layer is thicker than the second hole transport layer. In one embodiment, the first hole transport layer comprises a compound with the formula:

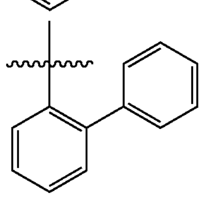


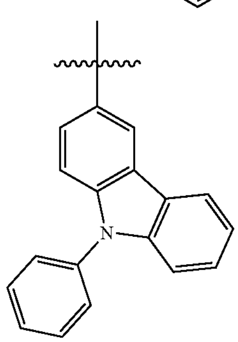
wherein Ar_a, Ar_b, Ar_c and Ar_d are independently selected from the group consisting of aryl and heteroaryl.

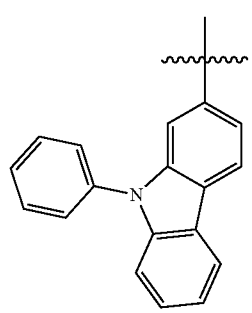
In one embodiment, the triplet energy of the compound of Formula II is higher than the emission energy of the emissive layer.

In one embodiment, Ar_1, Ar_2 and Ar_5 are independently selected from the group consisting of:

, , ,

,



, 

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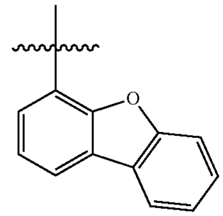
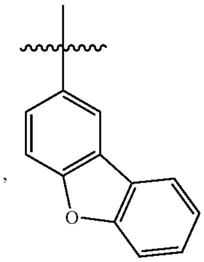


, 

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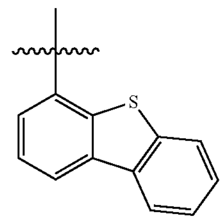
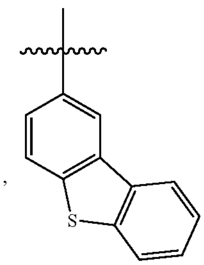


, 

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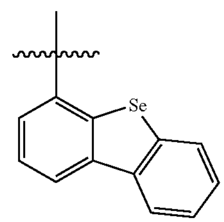
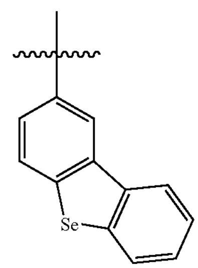


, 

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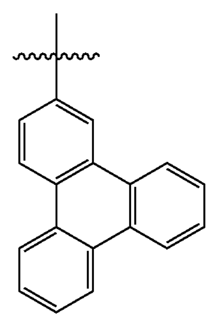
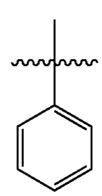
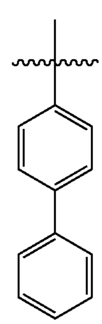
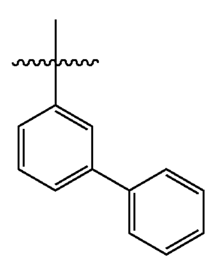
.

In one embodiment, Ar_1 and Ar_2 are independently selected from the group consisting of:

, , ,

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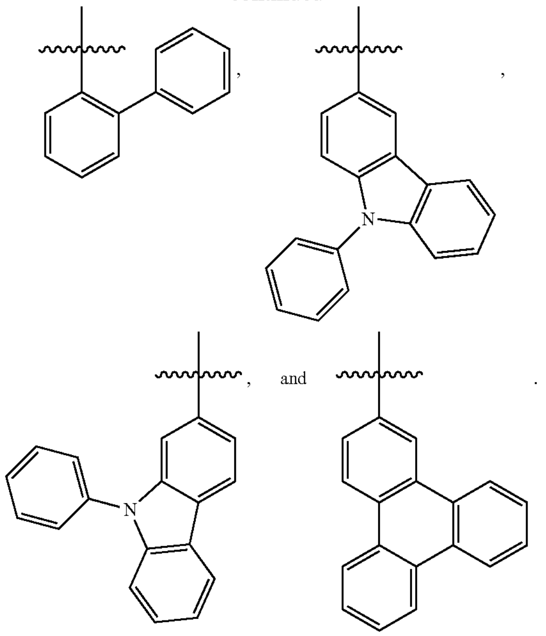
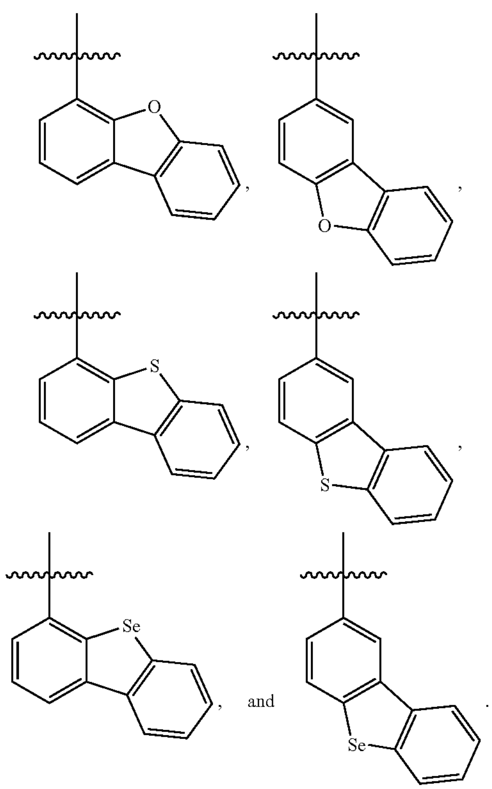
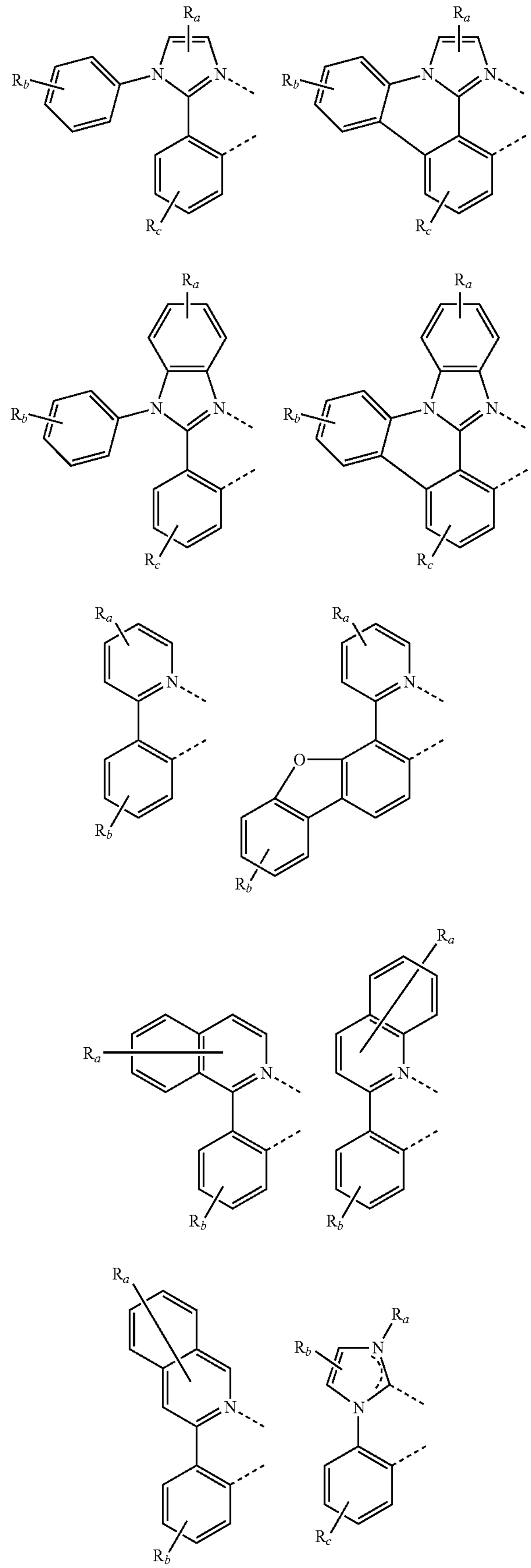


In one embodiment, Ar_1 and Ar_2 are independently selected from the group consisting of:



In one embodiment, the first device further comprises a first dopant material that is an emissive dopant comprising a transition metal complex having at least one ligand or part of the ligand if the ligand is more than bidentate selected from the group consisting of:



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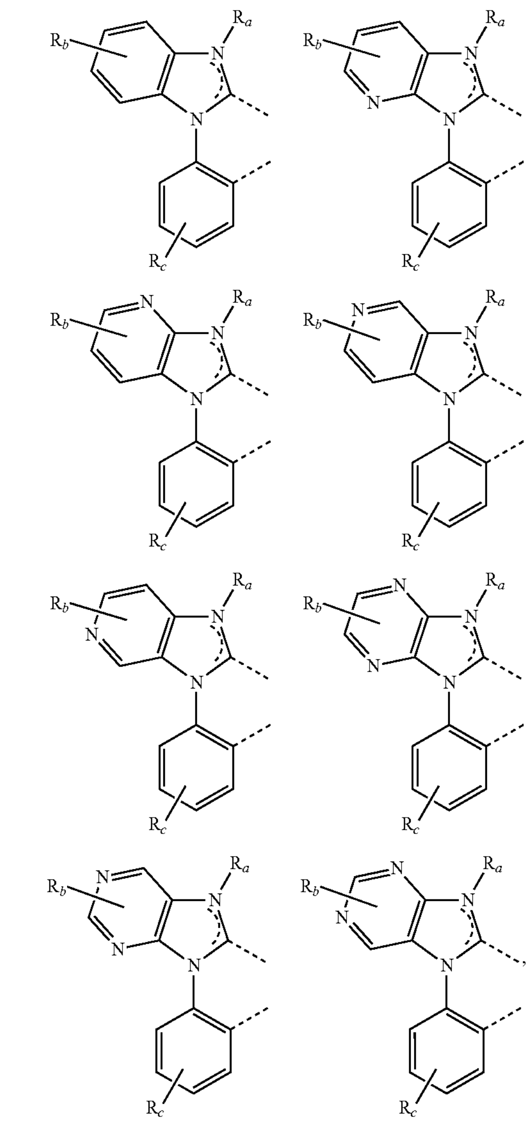

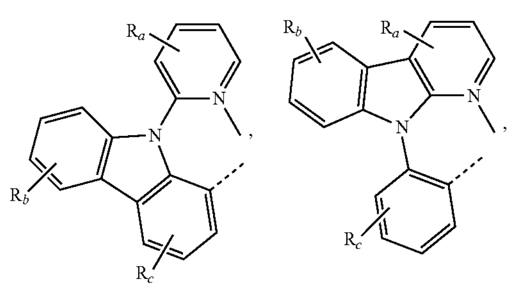

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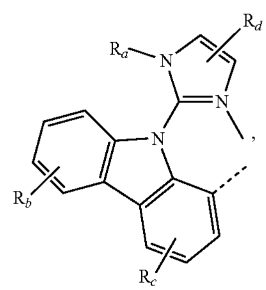
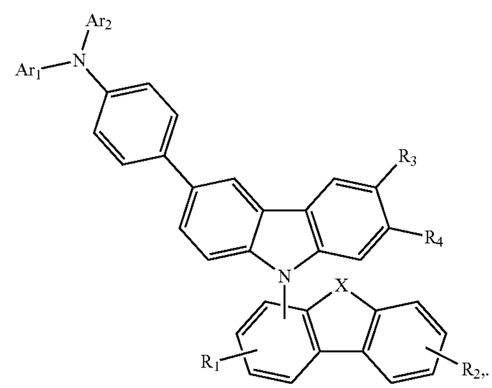


wherein R_a, R_b, R_c, and R_d may represent mono, di, tri, or tetra substitution, or no substitution and wherein R_a, R_b, R_c, and R_d are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, and wherein two adjacent substituents of R_a, R_b, R_c, and R_d are optionally joined to form a fused ring or form a multidentate ligand.

In one embodiment, the first device is a consumer product. In one embodiment, the first device is an organic light-emitting device. In one embodiment, the first device comprises a lighting panel. In one embodiment, a first device comprising an organic light emitting device, further comprising an anode, a cathode, a first organic layer disposed between the anode and the cathode, and wherein the first organic layer comprises a compound of formula:

Formula I



In the compound of Formula I, Ar_1 and Ar_2 are independently selected from the group consisting of aryl and heteroaryl, X is selected from the group consisting of O, S, and Se, R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution, and R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one embodiment, the first organic layer is an emissive layer. In one embodiment, the emissive layer is a phosphorescent emissive layer.

Device Examples

All OLED device examples were fabricated by high vacuum ($<10^{-7}$ Torr) thermal evaporation (VTE). The anode electrode is ~800 Å of indium tin oxide (ITO). The cathode consisted of 10 Å of LiF followed by 1,000 Å of A1. All devices were encapsulated with a glass lid sealed with an epoxy resin in a nitrogen glove box (<1 ppm of H_2O and O_2) and a moisture getter was incorporated inside the package.

The organic stack of the Device Examples in Table 2 consists of sequentially, from the ITO surface, 100 Å of LG101 (purchased from LG Chem) as the hole injection layer (HIL), 500 Å of NPD as the primary hole transporting layer (HTL), 50 Å of the secondary hole transporting layer, 300 Å of Compound A doped with 10% or 12% of phosphorescent dopant Compound B as the emissive layer (EML), 50 Å of Compound A as the ETL2 and 450 Å of Alq_3 as the ETL1.

Comparative Example 1 was fabricated in the same way except that there was no secondary hole transporting layer, and the thickness of the primary hole transporting layer was increased to 550 Å to match the combined thickness of the primary and secondary hole transporting layers in the Device Examples.

The structures of the aforementioned device components are as follows:

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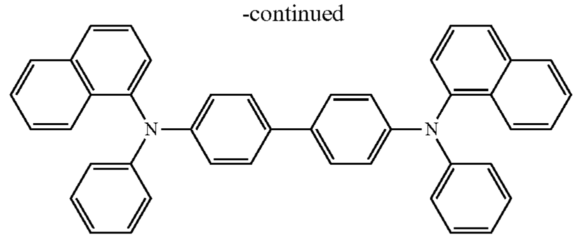
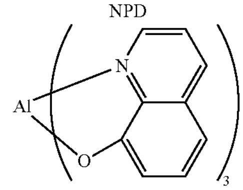


NPD



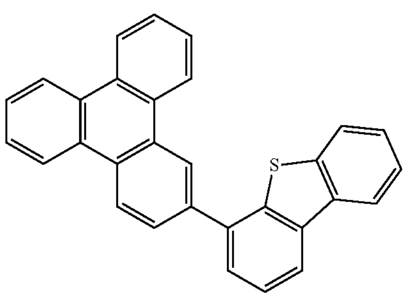
Alq_3

TABLE 2

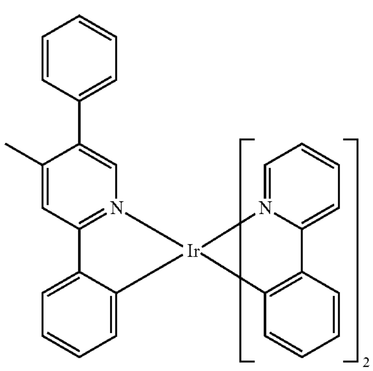
Device performance summary.

Example	Secondary HTL [50 Å]	EML [300 Å]	1931 CIE x	1931 CIE y	At L = 1000 cd/m² Voltage [V]	LE [cd/A]	EQE [%]	PE [lm/W]	At J = 40 mA/cm² L_0 [cd/m²]	LT_{80} [h]
Device Example 1	Compound 113	Compound A: Compound B 12%	0.330	0.624	4.9	76.5	20.9	49.0	25338	200
Device Example 2	Compound 178	Compound A: Compound B 10%	0.322	0.629	4.8	76.3	20.9	50.3	25112	422
Device Example 3	Compound 182	Compound A: Compound B 10%	0.322	0.629	4.7	75.5	20.7	50.3	24932	420
Comparative Device Example 1	none	Compound A: Compound B 12%	0.327	0.626	4.9	68.1	18.6	43.8	19596	290

Compound A

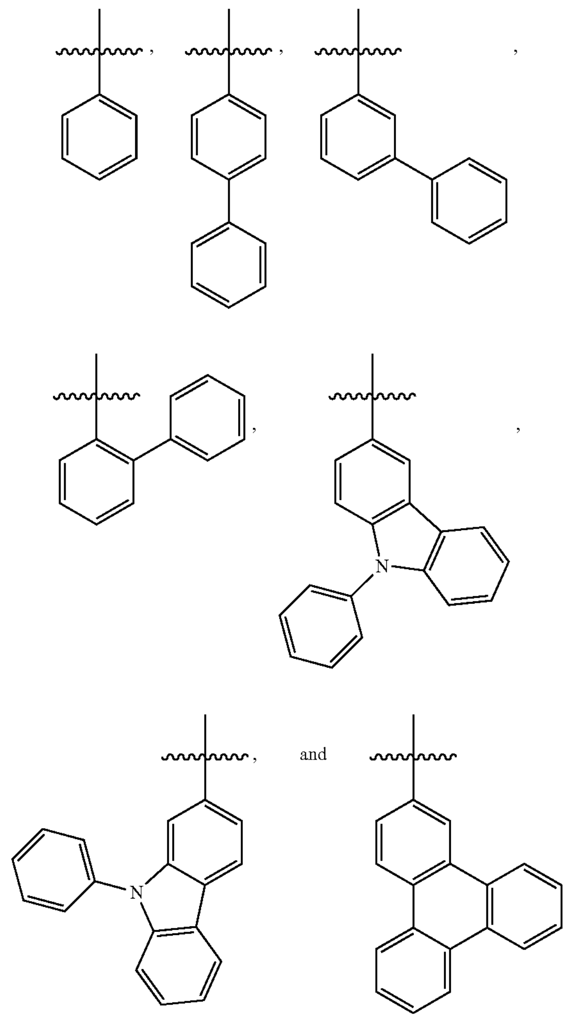


Compound B

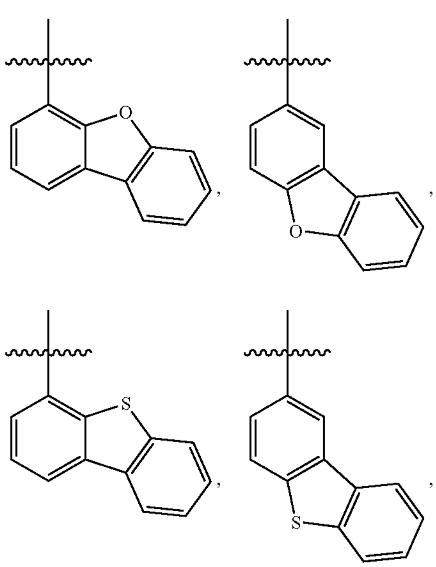


Device Examples 1-3 are the same as Comparative Device Example 1 except for the presence of the secondary HTL in former and the absence of the secondary HTL in latter. Device Examples 1-3 have Compounds 113, 178 and 182 respectively as the secondary HTL. The efficiencies of Device Examples 1-3 are higher (EQE=20.7-20.9%) than the efficiency of Comparative Device Example 1 (EQE=18.6%). The operation lifetimes of Device Examples 2 and 3 are remarkably high. The LT_{80}, the time required for the initial luminance (L_0) to drop to 80% of its initial value, at a constant current density of 40 mA/cm², is ~420 h, compared to 290 h of Comparative Device Example 1. Without being bound by theory, the improved efficiency and lifetime when Compounds 178 and 182 are used as the secondary HTL may be due to the high triplet energy, providing improved exciton confinement; the presence of a dibenzothiophene or triphenylene group, providing a high triplet, charge stabilization moiety; and a sufficiently shallow HOMO level (Compound 178 HOMO=−5.23 eV, Compound 182 HOMO=−5.21 eV, NPD HOMO=−5.17 eV) for hole transport.

Although hole conductivity may be reduced in compounds of Formula I or Formula II with respect to traditionally used triarylamine compounds such as NPD, compounds of Formula I and Formula II that bear substituents such as



at the Ar_1 and Ar_2 positions have better hole mobility that compounds bearing substituents such as



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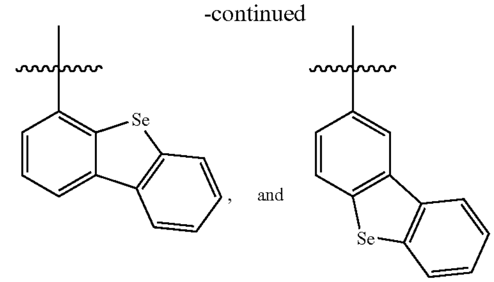


at these same positions because the latter group of substituents, deepens the HOMO levels, which causes a larger increase in hole conductivity. Additionally, although device lifetimes for a given thickness of the secondary HTL are sometimes reduced for compounds bearing Group 2 substituents compared with Group 1 substituents, this difference can be mitigated by decreasing the thickness of the secondary HTL.

The HOMO and LUMO levels and triplet energy are summarized in Table 3. The LT_{80} of Device Example 1 with Compound 113 as the secondary HTL is 200 h, less stable than Device. Example 1 (422 h) with Compound 178 as the secondary HTL. The difference between Compound 113 and Compound 178 is the $N(Ar_1)(Ar_2)$ group. In general, if the N is connected to a dibenzofuran or dibenzothiphene group, the HOMO gets deeper (Compound 1 HOMO=−5.31 eV, NPD HOMO=−5.17 eV) and hole conductivity may be reduced. This may lead to shorter device operation lifetime if the hole conductivity of the secondary HTL is not high enough, even though its thickness is kept low.

TABLE 3

HOMO, LUMO levels and triplet energy

Compound	HOMO (eV)*	LUMO (eV)*	Triplet energy (nm)#
NPD	−5.17	−1.98	500
Compound 113	−5.31	−1.98	436
Compound 178	−5.23	−1.99	450
Compound 182	−5.21	−2.04	450

*By solution electrochemistry using ferrocene as the standard

#By DFT/B3LYP/6-31 g (d) optimized geometry

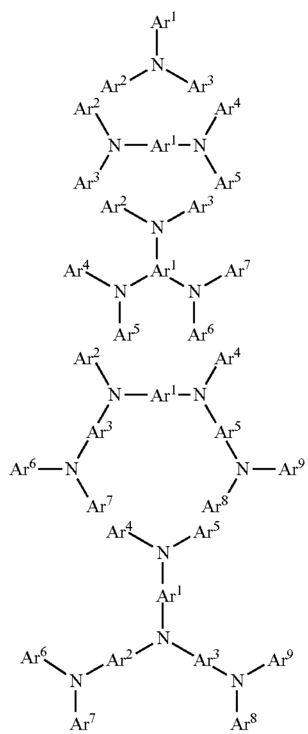
Combination with Other Materials

The materials described herein as useful for a particular layer in an organic light emitting device may be used in combination with a wide variety of other materials present in the device. For example, emissive dopants disclosed herein may be used in conjunction with a wide variety of hosts, transport layers, blocking layers, injection layers, electrodes and other layers that may be present. The materials described or referred to below are non-limiting examples of materials that may be useful in combination with the compounds disclosed herein, and one of skill in the art can readily consult the literature to identify other materials that may be useful in combination.

HIL/HTL:

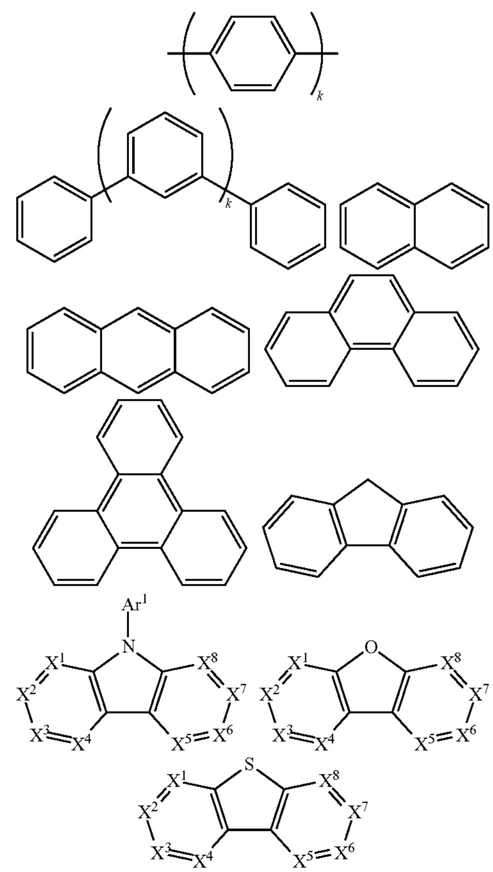
A hole injecting/transporting material to be used in the present invention is not particularly limited, and any compound may be used as long as the compound is typically used as a hole injecting/transporting material. Examples of the material include, but not limit to: a phthalocyanine or porphryin derivative; an aromatic amine derivative; an indolocarbazole derivative; a polymer containing fluorohydrocarbon; a polymer with conductivity dopants; a conducting polymer, such as PEDOT/PSS; a self-assembly monomer derived from compounds such as phosphonic acid and sliane derivatives; a metal oxide derivative, such as MoO_x; a p-type semiconducting organic compound, such as 1,4,5,8,9,12-Hexaazatriphenylenehexacarbonitrile; a metal complex, and a cross-linkable compounds.

Examples of aromatic amine derivatives used in HIL or HTL include, but not limit to the following general structures:



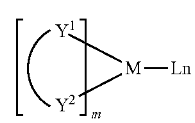
Each of Ar^1 to Ar^9 is selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each Ar is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfonyl, sulfonyl, phosphine, and combinations thereof.

In one aspect, Ar^1 to Ar^9 is independently selected from the group consisting of:



k is an integer from 1 to 20; X^1 to X^8 is C (including CH) or N; Ar^1 has the same group defined above.

Examples of metal complexes used in HIL or HTL include, but not limit to the following general formula:



M is a metal, having an atomic weight greater than 40; (Y^1—Y^2) is a bidentate ligand, Y^1 and Y^2 are independently selected from C, N, O, P, and S; L is an ancillary ligand; m is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and m+n is the maximum number of ligands that may be attached to the metal.

In one aspect, (Y^1—Y^2) is a 2-phenylpyridine derivative.

In another aspect, (Y^1—Y^2) is a carbene ligand.

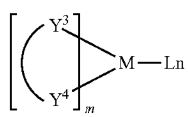
In another aspect, M is selected from Ir, Pt, Os, and Zn.

In a further aspect, the metal complex has a smallest oxidation potential in solution vs. Fc^+/Fc couple less than about 0.6 V.

Host:

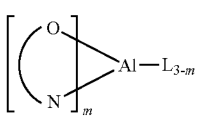
The light emitting layer of the organic EL device of the present invention preferably contains at least a metal complex as light emitting material, and may contain a host material using the metal complex as a dopant material. Examples of the host material are not particularly limited, and any metal complexes or organic compounds may be used as long as the triplet energy of the host is larger than that of the dopant. While the Table below categorizes host materials as preferred for devices that emit various colors, any host material may be used with any dopant so long as the triplet criteria is satisfied.

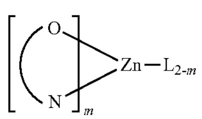
Examples of metal complexes used as host are preferred to have the following general formula:



M is a metal; (Y^3—Y^4) is a bidentate ligand, Y^3 and Y^4 are independently selected from C, N, O, P, and S; L is an ancillary ligand; m is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and m+n is the maximum number of ligands that may be attached to the metal.

In one aspect, the metal complexes are:





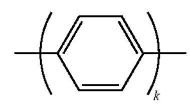
(O—N) is a bidentate ligand, having metal coordinated to atoms O and N.

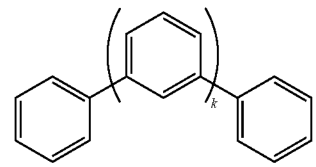
In another aspect, M is selected from Ir and Pt.

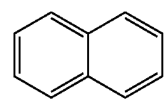
In a further aspect, (Y^3—Y^4) is a carbene ligand.

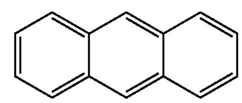
Examples of organic compounds used as host are selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each group is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfonyl, sulfonyl, phosphino, and combinations thereof.

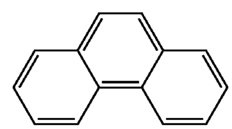
In one aspect, host compound contains at least one of the following groups in the molecule:

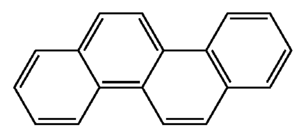


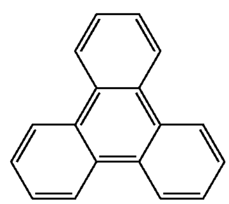


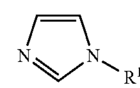


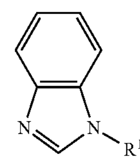


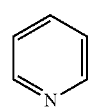


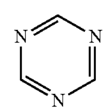


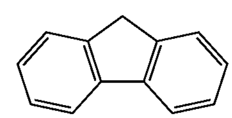


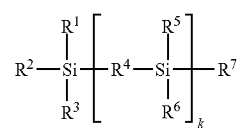


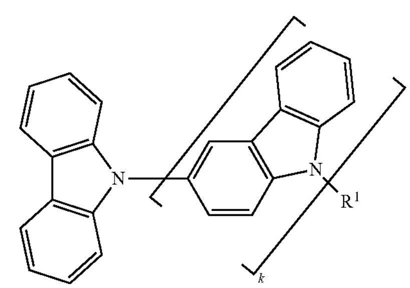


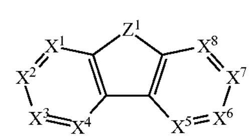


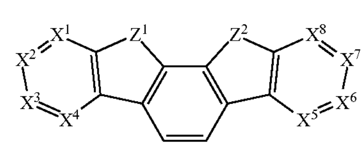












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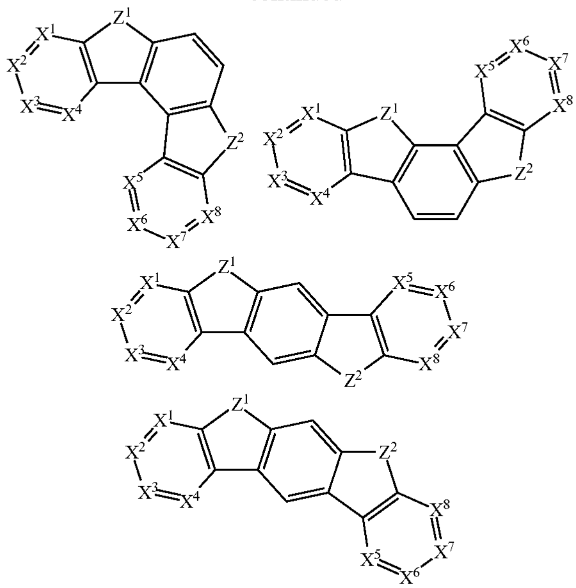


R¹ to R⁷ is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above.

k is an integer from 0 to 20.

X^1 to X^8 is selected from C (including CH) or N.

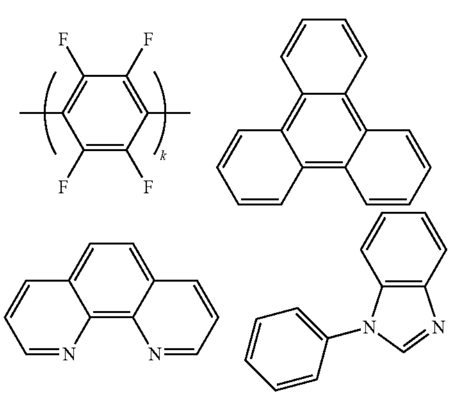
Z^1 and Z^2 is selected from NR^1, O, or S.

HBL:

A hole blocking layer (HBL) may be used to reduce the number of holes and/or excitons that leave the emissive layer. The presence of such a blocking layer in a device may result in substantially higher efficiencies as compared to a similar device lacking a blocking layer. Also, a blocking layer may be used to confine emission to a desired region of an OLED.

In one aspect, compound used in HBL contains the same molecule or the same functional groups used as host described above.

In another aspect, compound used in HBL contains at least one of the following groups in the molecule:



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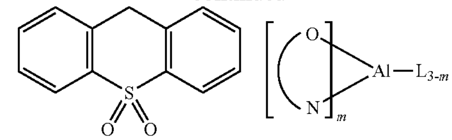
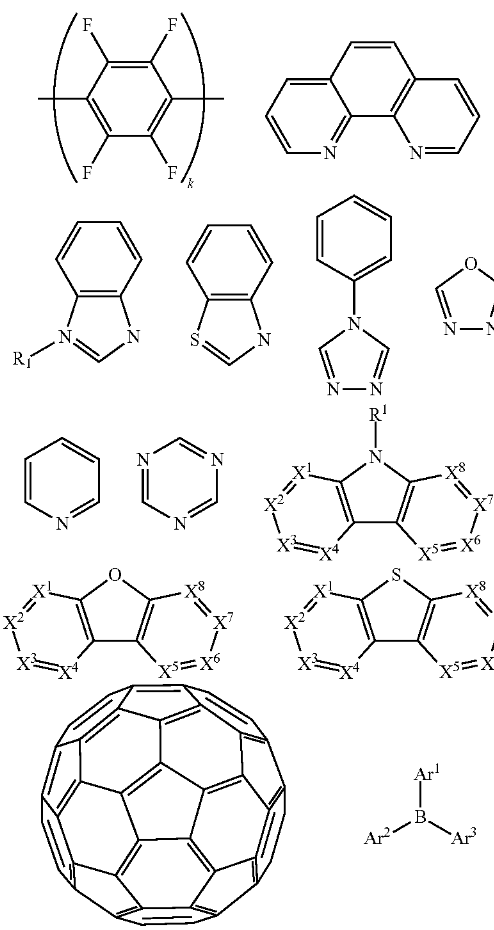


k is an integer from 0 to 20; L is an ancillary ligand, m is an integer from 1 to 3.

ETL:

Electron transport layer (ETL) may include a material capable of transporting electrons. Electron transport layer may be intrinsic (undoped), or doped. Doping may be used to enhance conductivity. Examples of the ETL material are not particularly limited, and any metal complexes or organic compounds may be used as long as they are typically used to transport electrons.

In one aspect, compound used in ETL contains at least one of the following groups in the molecule:



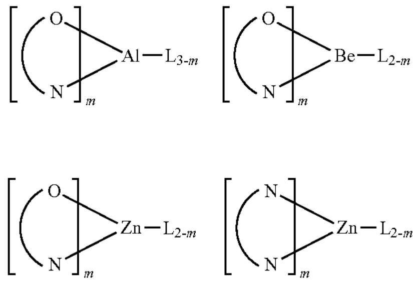
R^1 is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above.

Ar^1 to Ar^3 has the similar definition as Ar's mentioned above.

k is an integer from 0 to 20.

X^1 to X^8 is selected from C (including CH) or N.

In another aspect, the metal complexes used in ETL contains, but not limit to the following general formula:



(O—N) or (N—N) is a bidentate ligand, having metal coordinated to atoms O, N or N,N; L is an ancillary ligand; m is an integer value from 1 to the maximum number of ligands that may be attached to the metal.

In any above-mentioned compounds used in each layer of the OLED device, the hydrogen atoms can be partially or fully deuterated.

In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exiton/hole blocking layer materials, electron transporting and electron injecting materials may be used in an OLED. Non-limiting examples of the materials that may be used in an OLED in combination with materials disclosed herein are listed in Table 4 below. Table 4 lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE 4

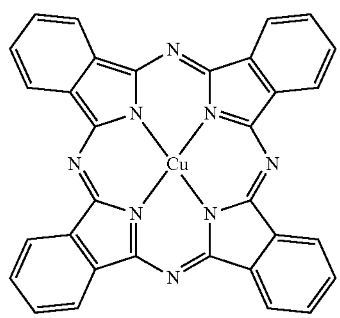
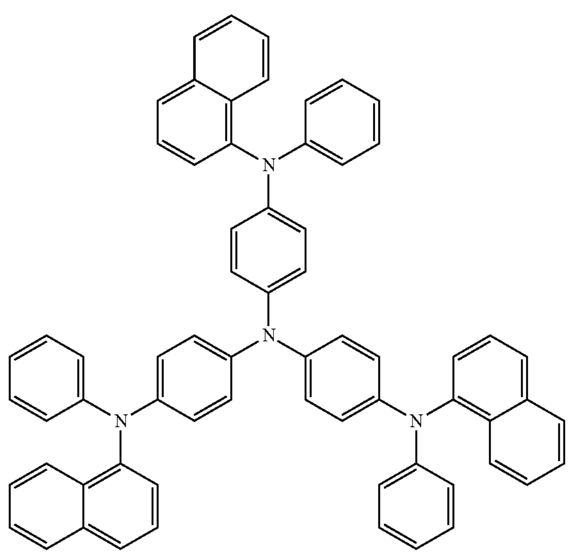
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Phthalocyanine and porphryin compounds		Appl. Phys. Lett. 69, 2160 (1996)
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)
CF_x Fluorohydrocarbon polymer	$-[CH_xF_y]_n-$	Appl. Phys. Lett. 78, 673 (2001)

TABLE 4-continued

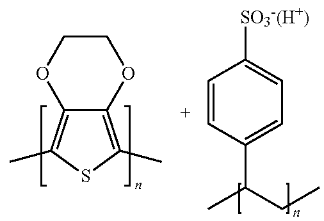
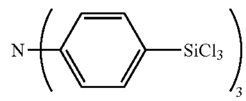
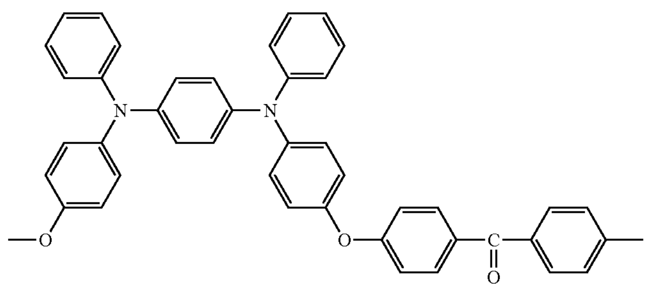
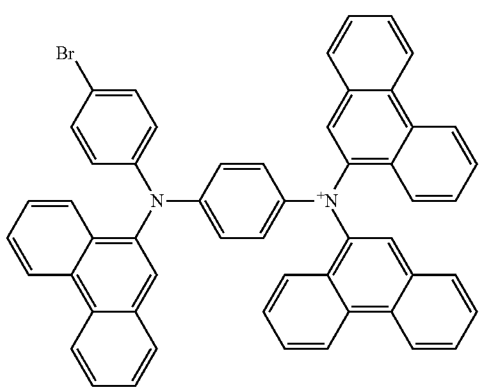
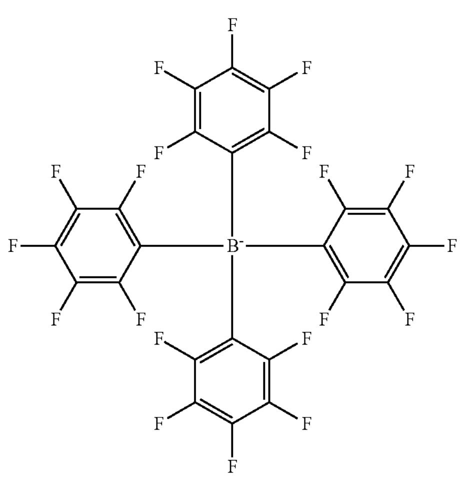
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polypthiophene)		Synth. Met. 87, 171 (1997) WO2007002683
Phosphonic acid and sliane SAMs		US20030162053
Triarylamine or polythiophene polymers with conductivity dopants	 and  	EP1725079A1

TABLE 4-continued

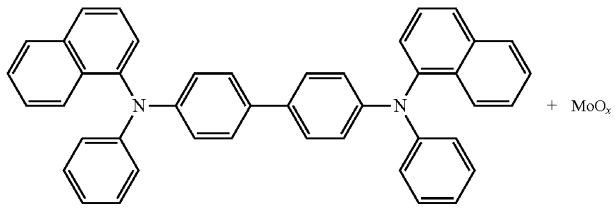
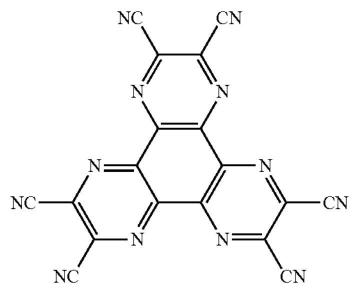
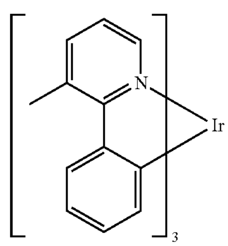
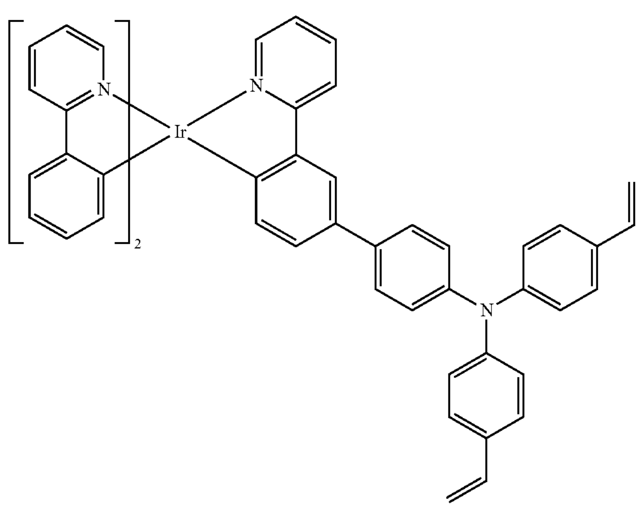
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Organic compounds with conductive inorganic compounds, such as molybdenum and tungsten oxides		US20050123751 SID Symposium Digest, 37, 923 (2006) WO2009018009
n-type semiconducting organic complexes		US20020158242
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265

TABLE 4-continued

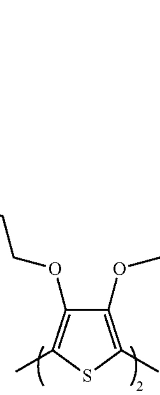
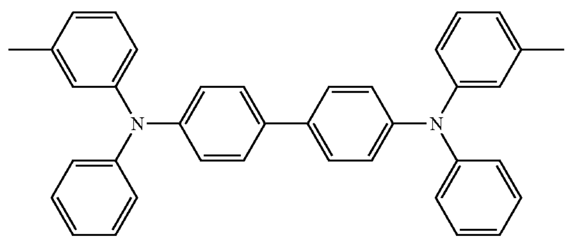
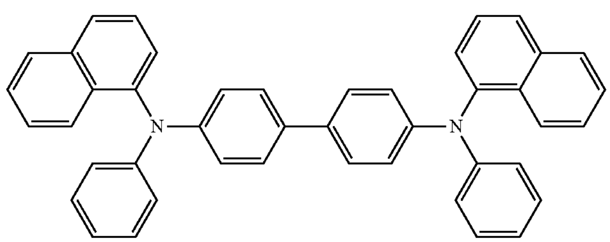
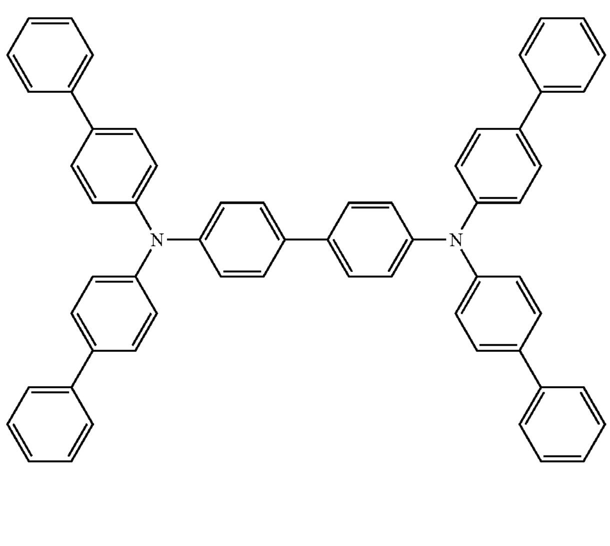
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Polythiophene based polymers and copolymers		WO2011075644 EP2350216
	Hole transporting materials	
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987)
		US5061569
		EP650955

TABLE 4-continued

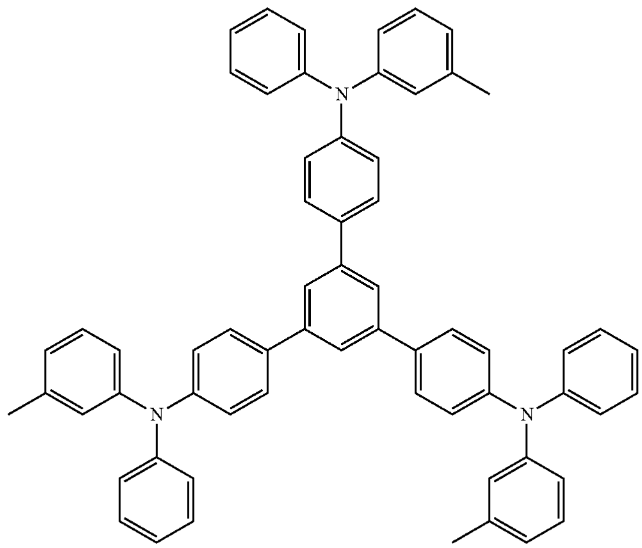
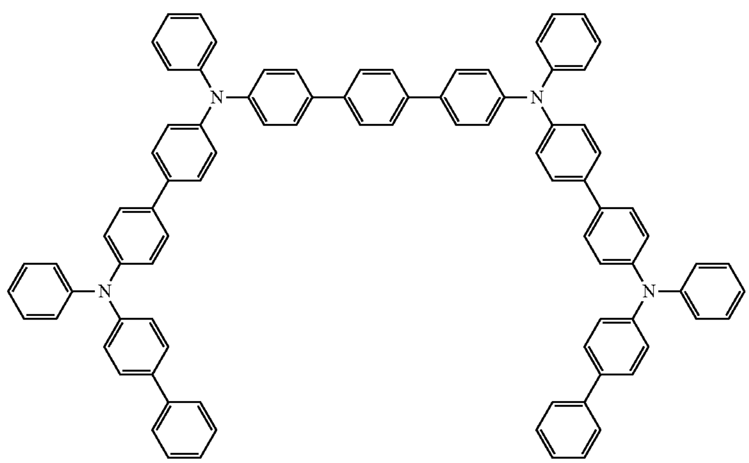
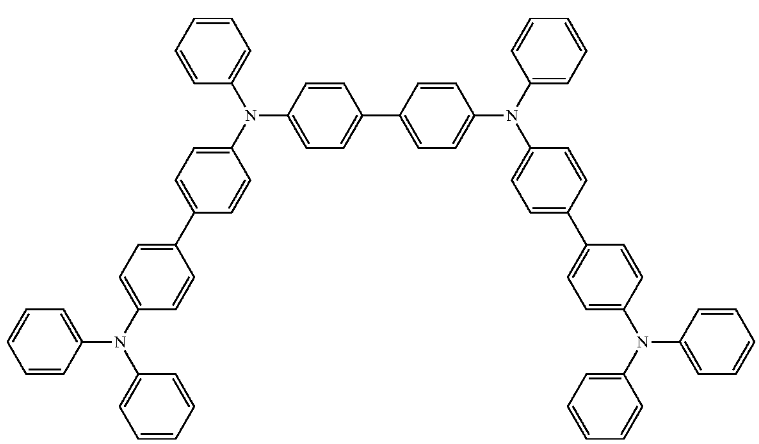
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		J. Mater. Chem. 3, 319 (1993)
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)

TABLE 4-continued

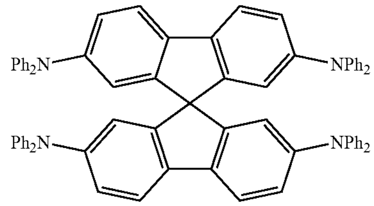
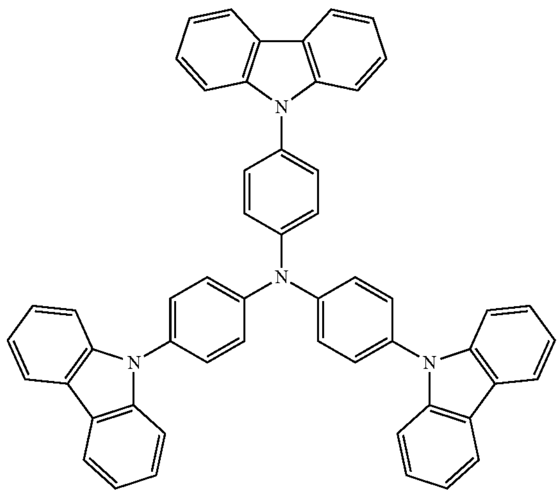
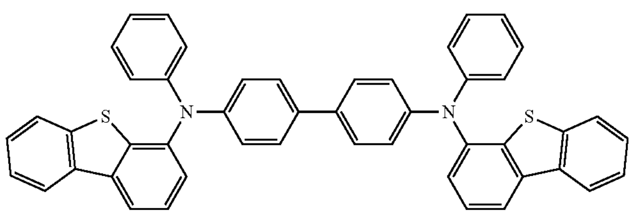
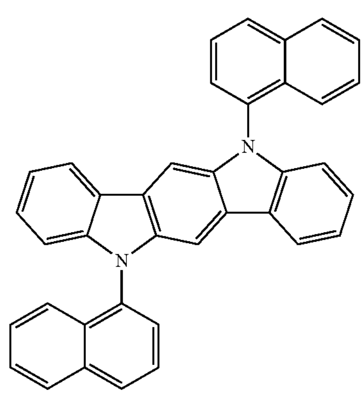
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triaylamine on spirofluorene core		Synth. Met. 91, 209 (1997)
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572
Triarylamine with (di)benzothiophene/(di)benzofuran		US20070278938, US20080106190 US20110163302
Indolocarbazoles		Synth. Met. 111, 421 (2000)

TABLE 4-continued

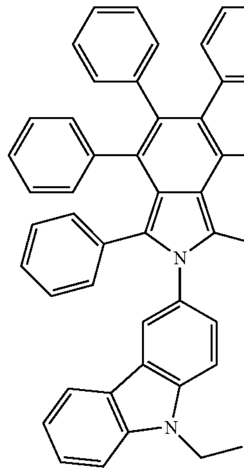
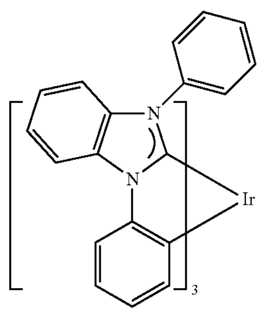
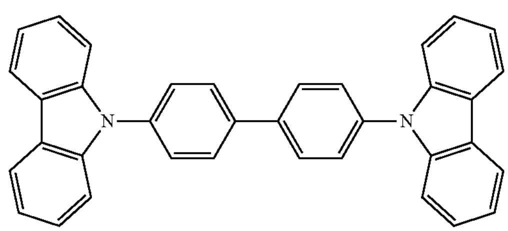
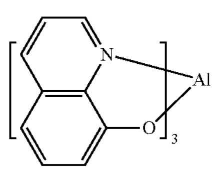
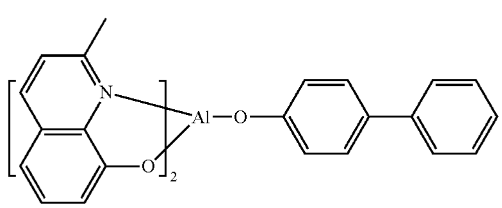
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
Metal carbene complexes		US20080018221
	Phosphorescent OLED host materials Red hosts	
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)
		US20060202194

TABLE 4-continued

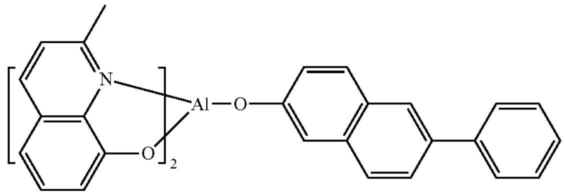
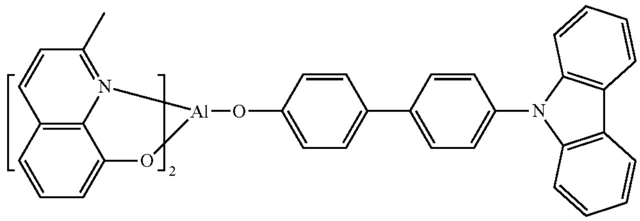
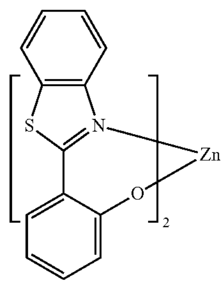
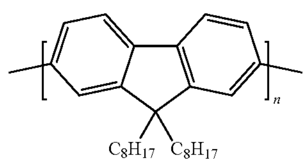
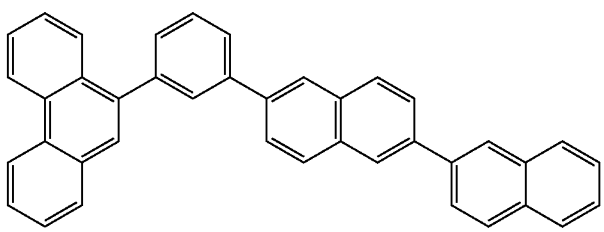
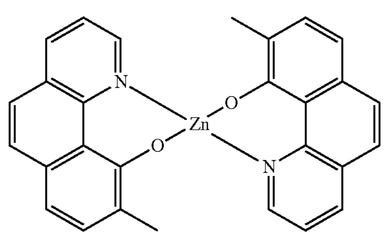
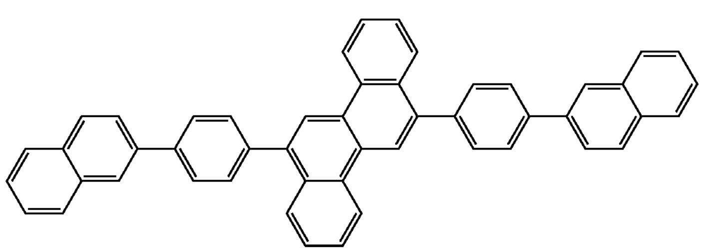
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2005014551
		WO2006072002
Metal phenoxybenzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
Aromatic fused rings		WO2009066779, WO2009066778, WO2009063833, US20090045731, US20090045730, WO2009008311, US20090008605, US20090009065
Zinc complexes		WO2010056066
Chrysene based compounds		WO2011086863

TABLE 4-continued

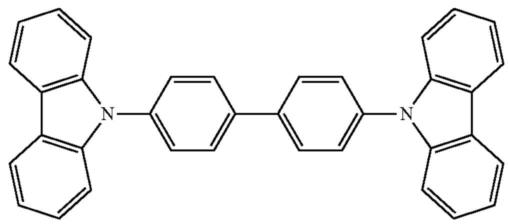
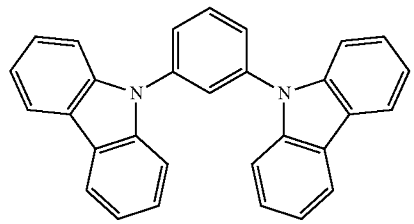
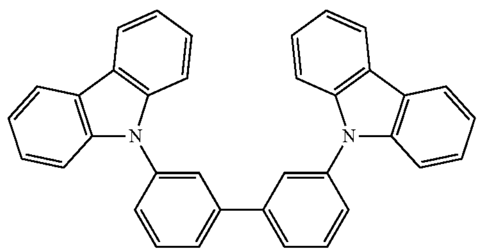
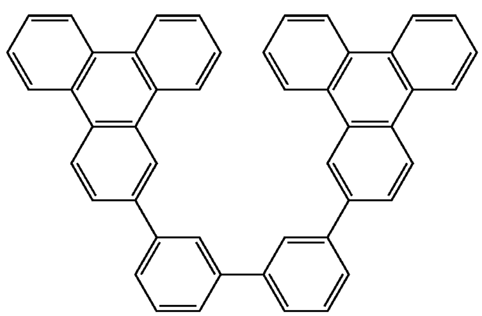
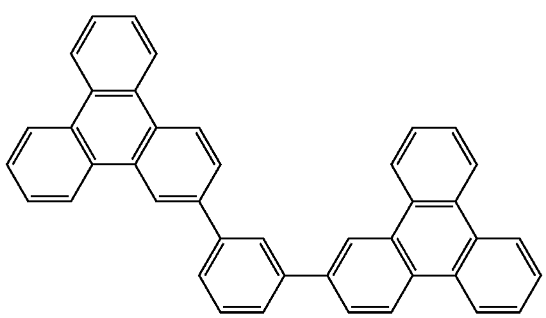
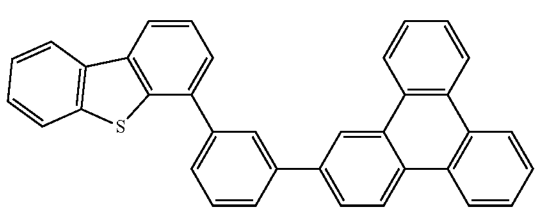
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Green hosts	
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
		US20030175553
		WO2001039234
Aryltriphenylene compounds		US20060280965
		US20060280965
		WO2009021126

TABLE 4-continued

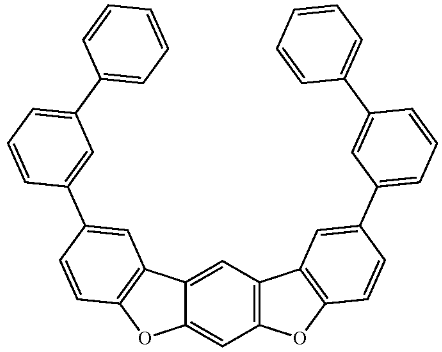
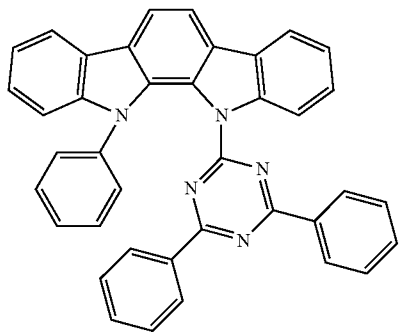
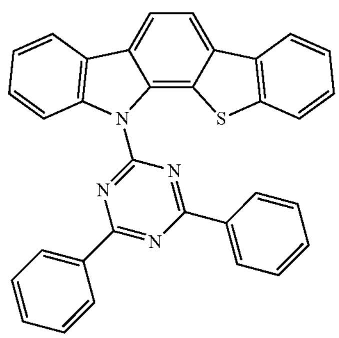
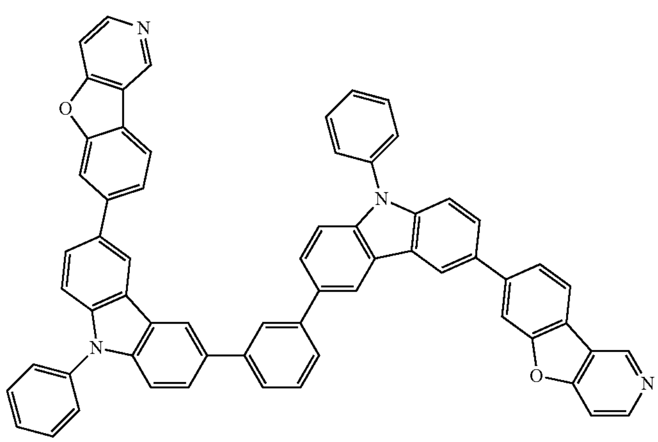
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Poly-fused heteroaryl compounds		US20090309488 US20090302743 US20100012931
Donor acceptor type molecules		WO2008056746
		WO2010107244
Aza-carbazole/ DBT/DBF		JP2008074939

TABLE 4-continued

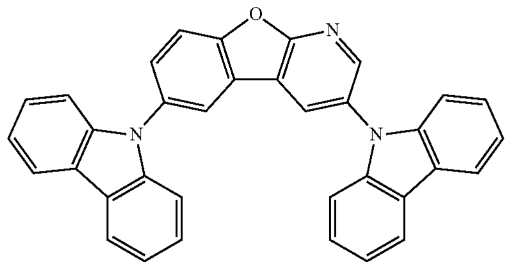
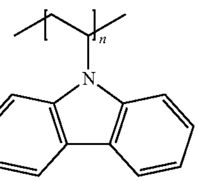
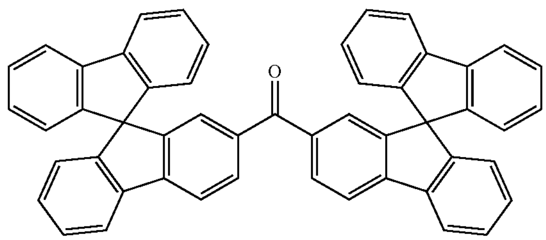
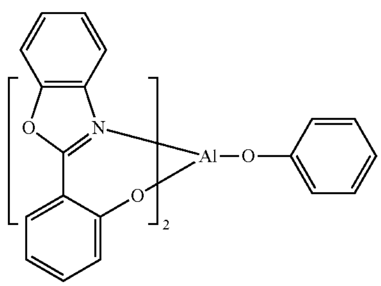
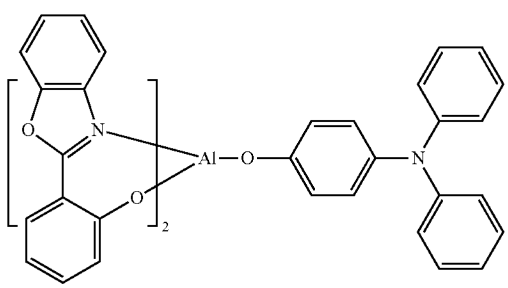
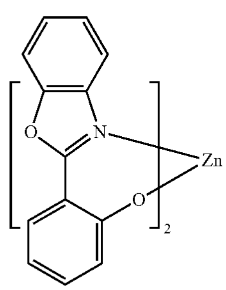
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20100187984
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207
Metal phenoxybenzooxazole compounds		WO2005089025
		WO2006132173
		JP200511610

TABLE 4-continued

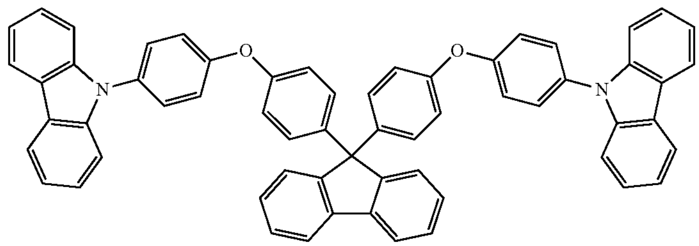
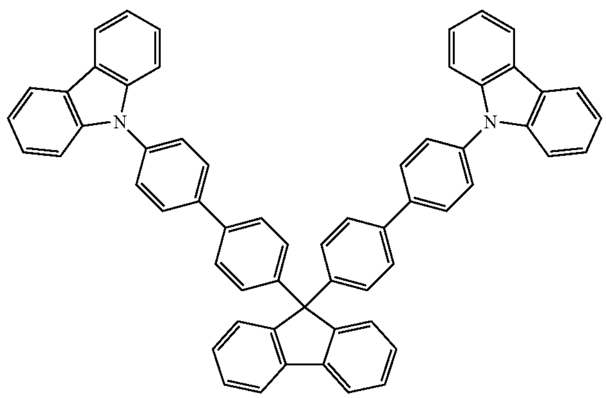
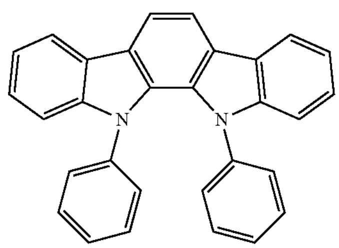
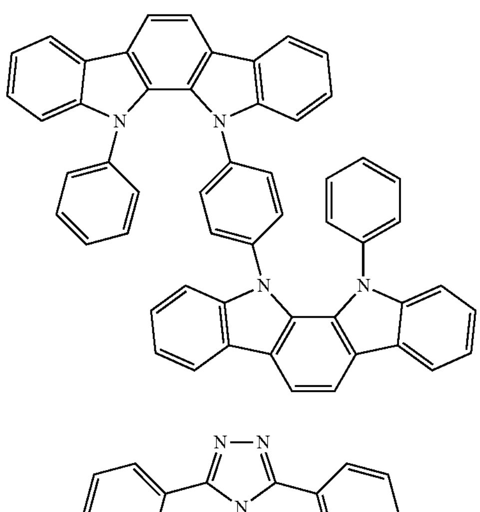
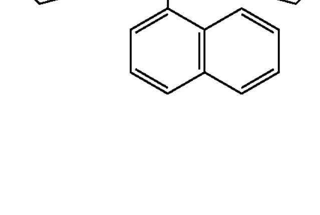
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297
Indolocabazoles		WO2007063796
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)

TABLE 4-continued

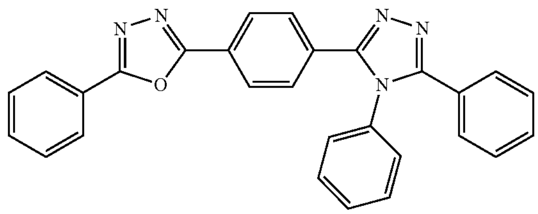
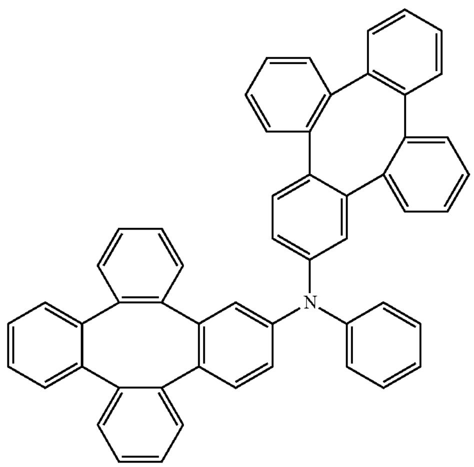
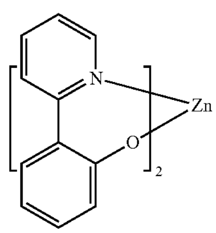
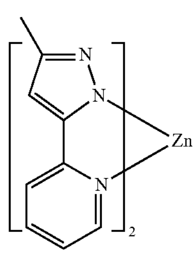
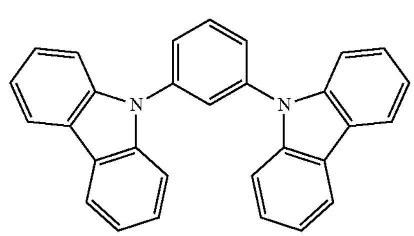
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2004107822
Tetraphenylene complexes		US20050112407
Metal phenoxypyridine compounds		WO2005030900
Metal coordination complexes (e.g., Zn, Al with N^N ligands)		US20040137268, US20040137267
	Blue hosts	
Arylcarbazoles		Appl. Phys. Lett, 82, 2422 (2003)

TABLE 4-continued

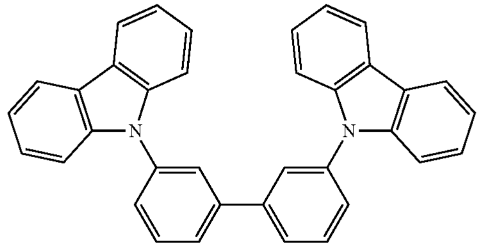
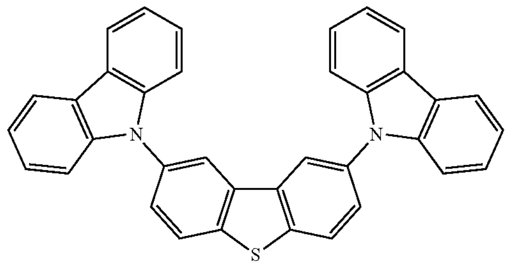
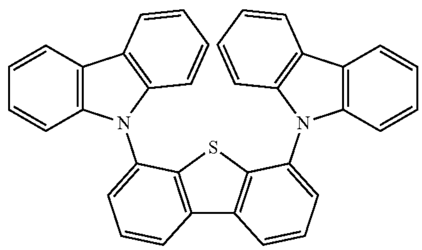
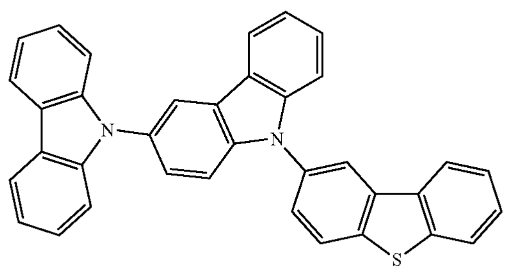
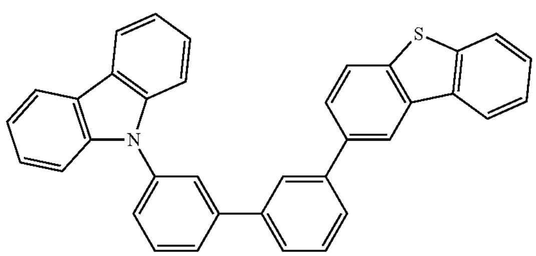
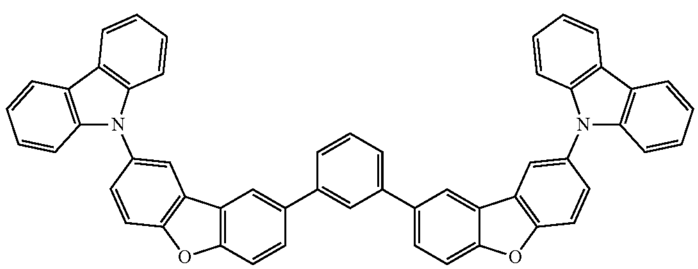
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070190359
Dibenzothiophene/ Dibenzofuran-carbazole compounds		WO2006114966, US20090167162
		US20090167162
		WO2009086028
		US20090030202, US20090017330
		US20100084966

TABLE 4-continued

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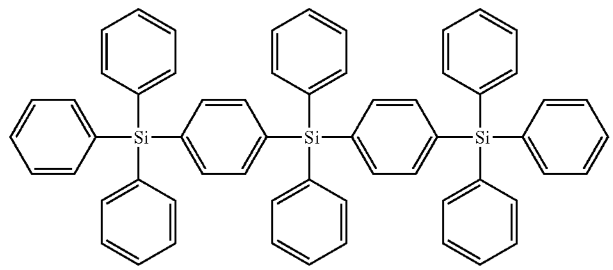
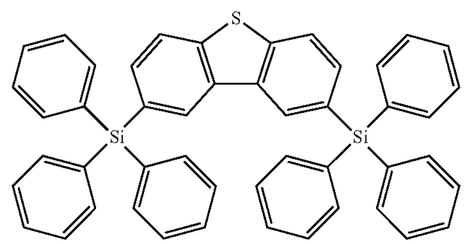
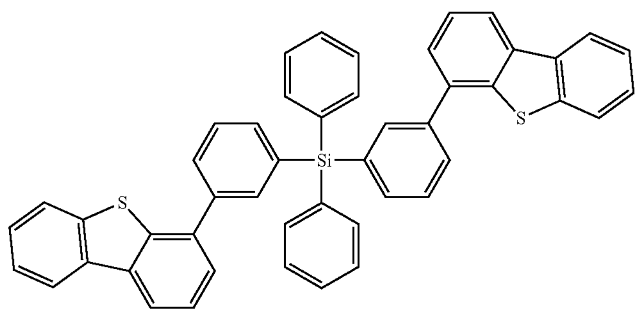
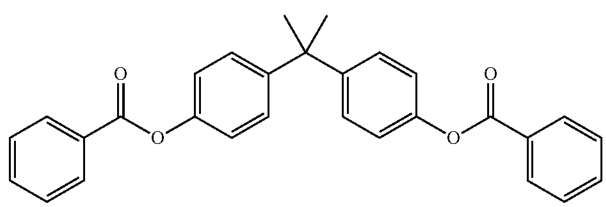
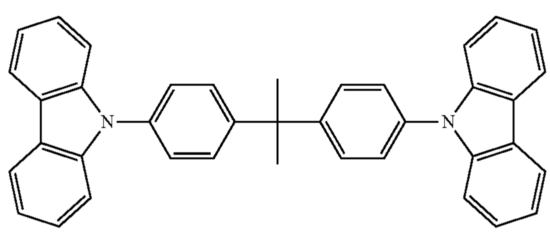
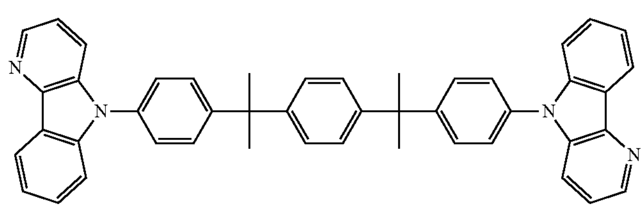
Silicon aryl compounds		US20050238919
		WO2009003898
Silicon/ Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
Carbazole linked by non-conjugated groups		US20040115476
Aza-carbazoles		US20060121308

TABLE 4-continued

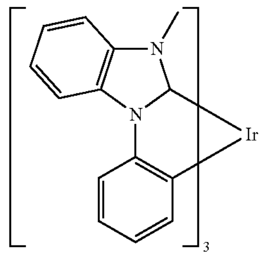
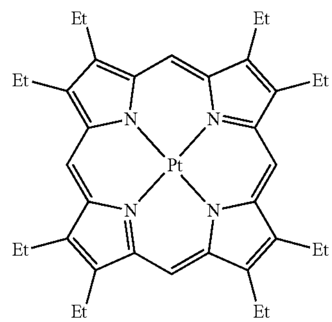
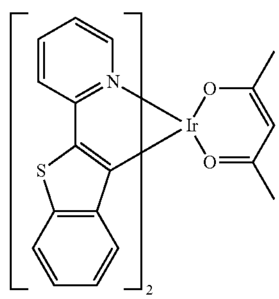
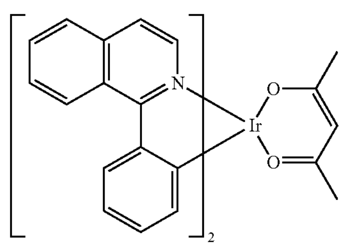
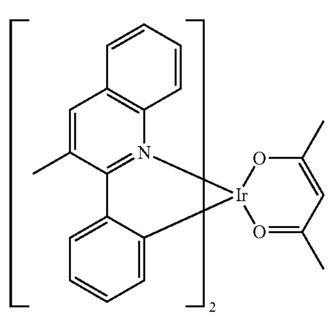
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
High triplet metal organometallic complex		US7154114
	Phosphorescent dopants Red dopants	
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium(III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US2006835469
		US2006835469

TABLE 4-continued

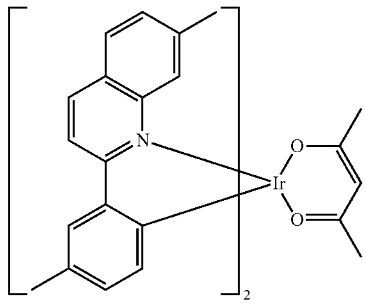
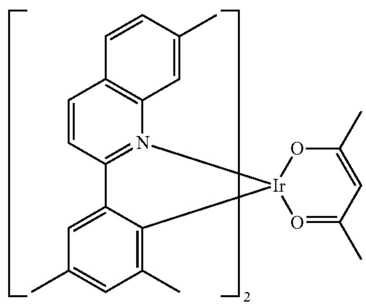
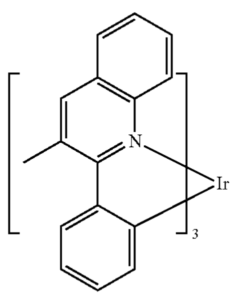
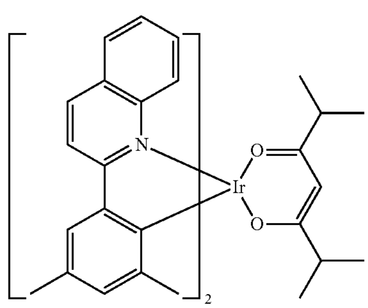
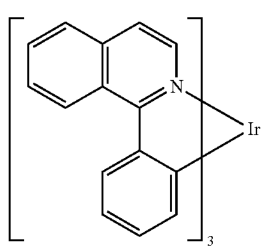
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060202194
		US20060202194
		US20070087321
		US20080261076 US20100090591
		US20070087321

TABLE 4-continued

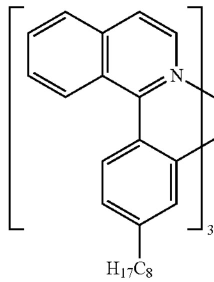
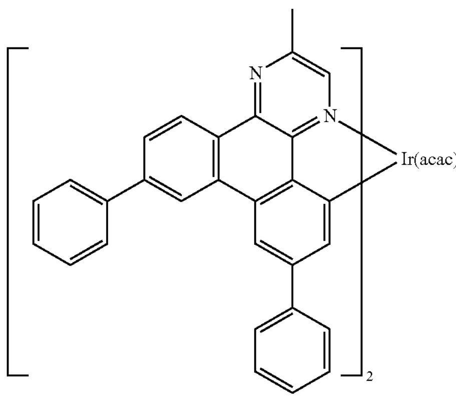
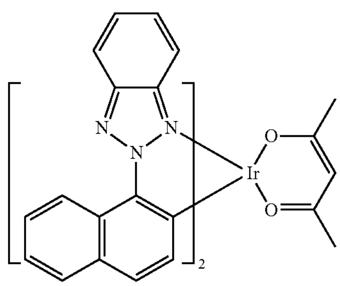
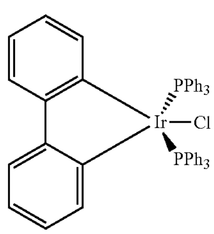
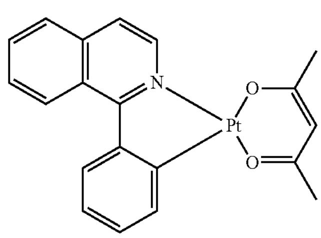
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 19, 739 (2007)
		WO2009100991
		WO2008101842
		US7232618
Platinum(II) organometallic complexes		WO2003040257

TABLE 4-continued

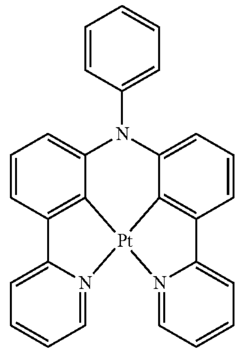
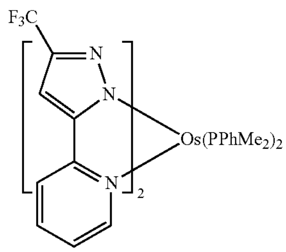
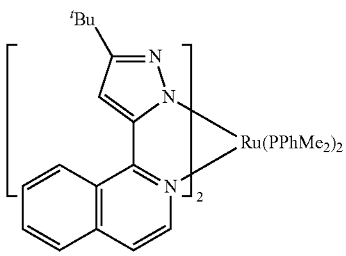
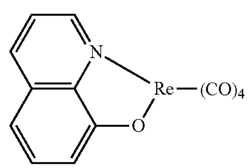
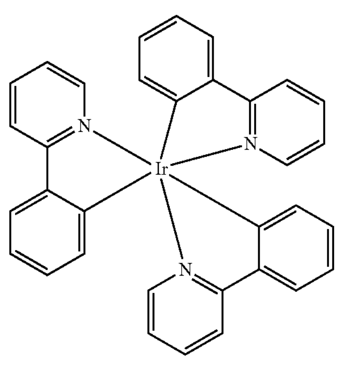
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070103060
Osminum(III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium(II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
	Green dopants	
Iridium(III) organometallic complexes	 and its derivatives	Inorg. Chem. 40, 1704 (2001)

TABLE 4-continued

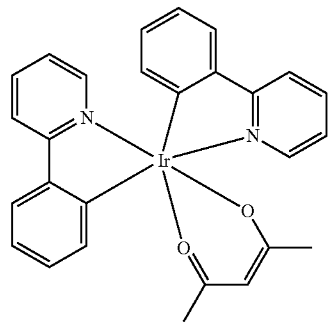
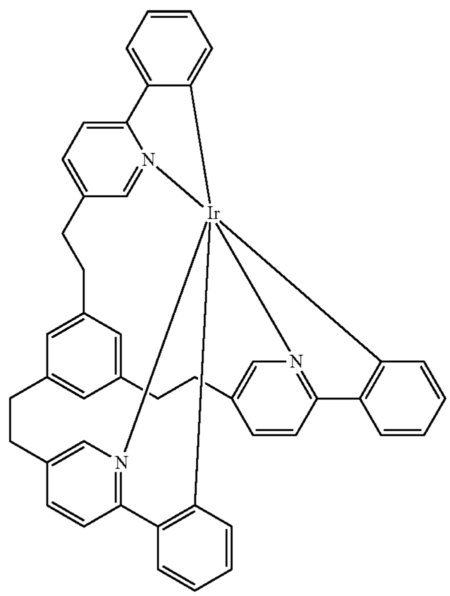
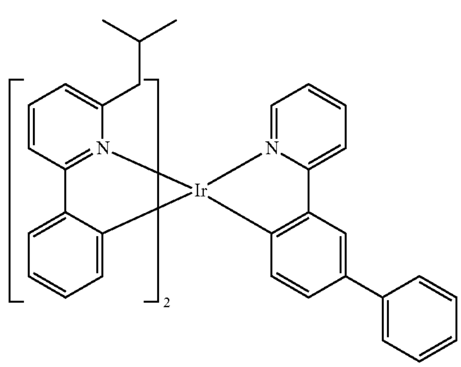
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20020034656
		US7332232
		US20090108737

TABLE 4-continued

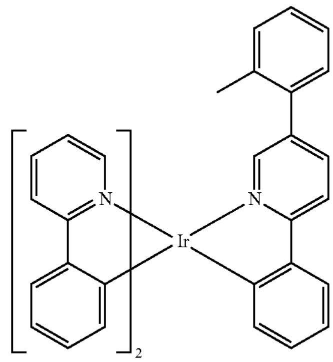
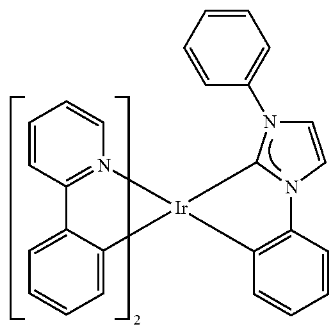
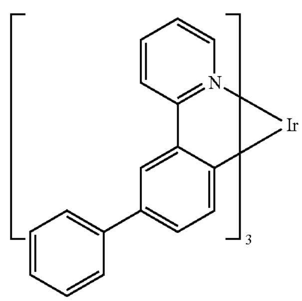
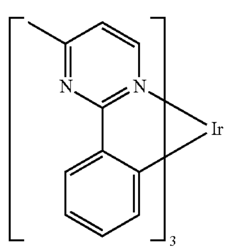
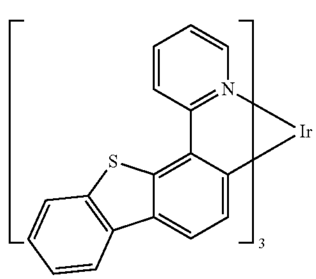
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2010028151
		EP1841834B
		US20060127696
		US20090039776
		US6921915

TABLE 4-continued

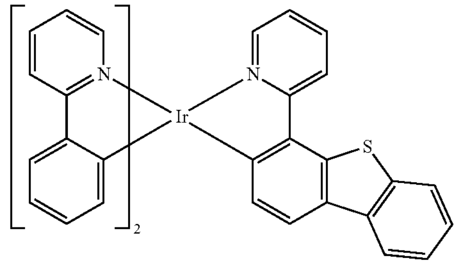
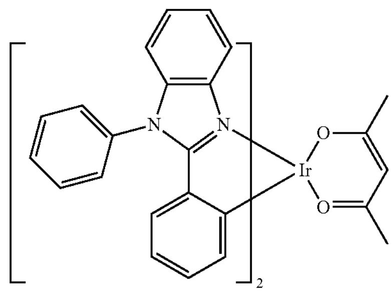
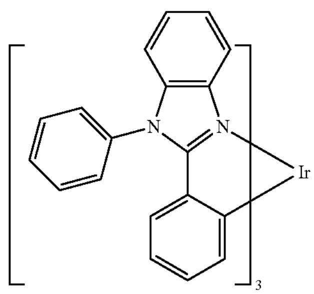
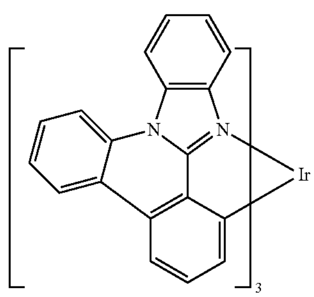
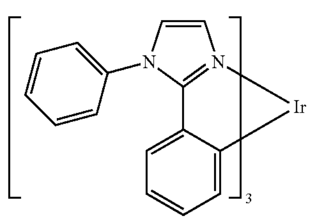
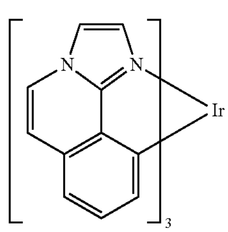
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20100244004
		US6687266
		Chem. Mater. 16, 2480 (2004)
		US20070190359
		US20060008670 JP2007123392
		WO2010086089, WO2011044988

TABLE 4-continued

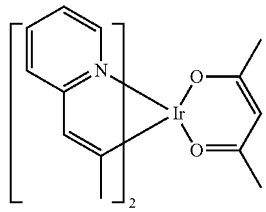
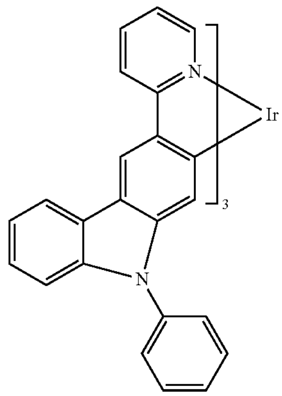
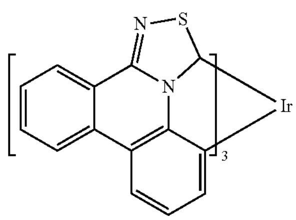
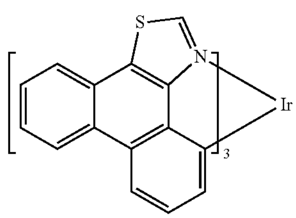
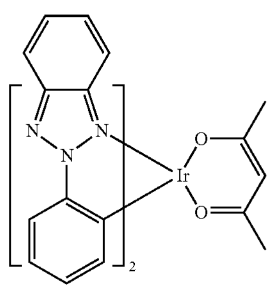
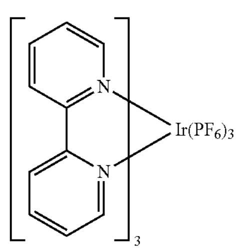
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Adv. Mater. 16, 2003 (2004)
		Angew. Chem. Int. Ed. 2006, 45, 7800
		WO2009050290
		US20090165846
		US20080015355
		US20010015432

TABLE 4-continued

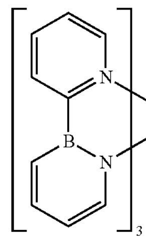
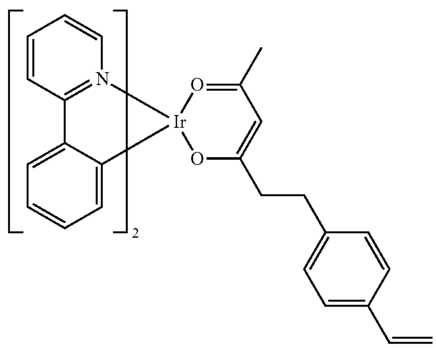
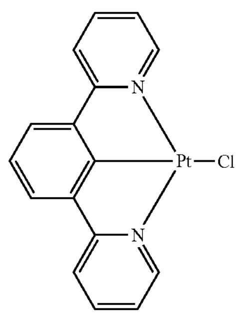
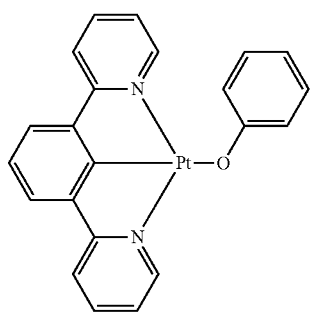
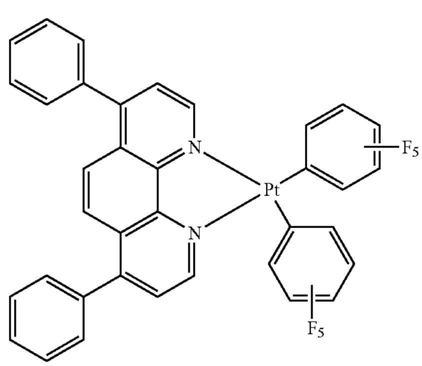
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20100295032
Monomer for polymeric metal organometallic compounds		US7250226, US7396598
Pt(II) organometallic complexes, including polydentated ligands		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)
		Chem. Lett. 34, 592 (2005)

TABLE 4-continued

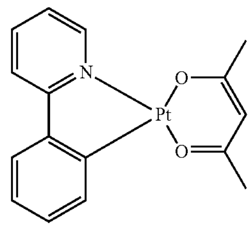
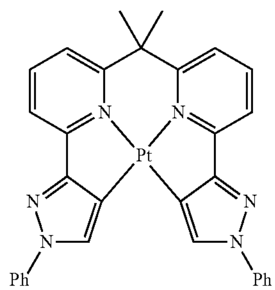
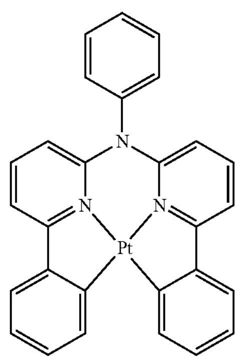
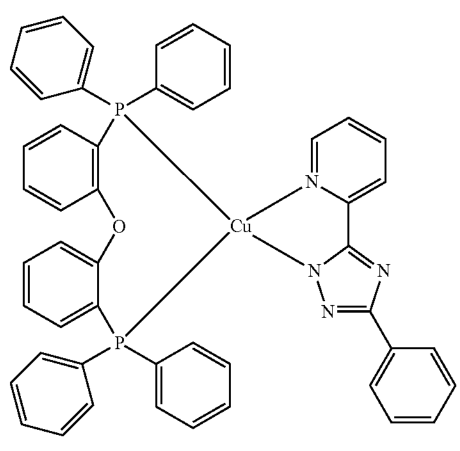
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2002015645
		US20060263635
		US20060182992 US20070103060
Cu complexes		WO2009000673

TABLE 4-continued

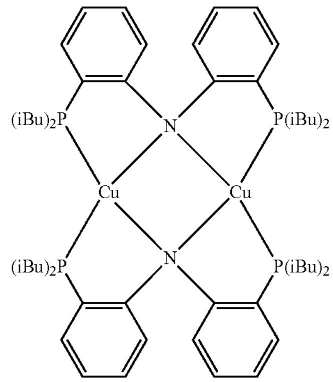
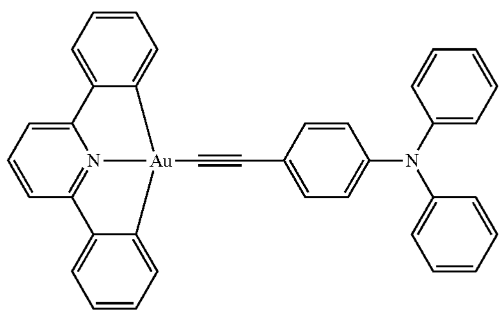
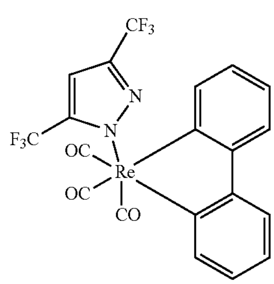
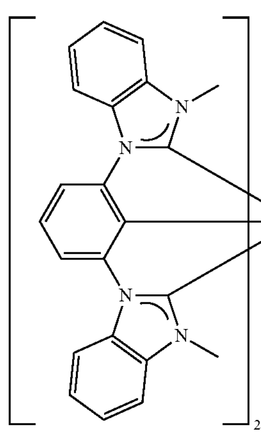
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070111026
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium(III) complexes		Inorg. Chem. 42, 1248 (2003)
Osmium(II) complexes		US7279704

TABLE 4-continued

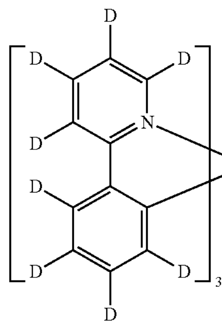
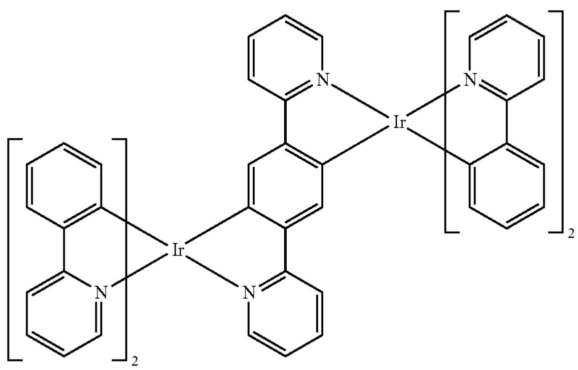
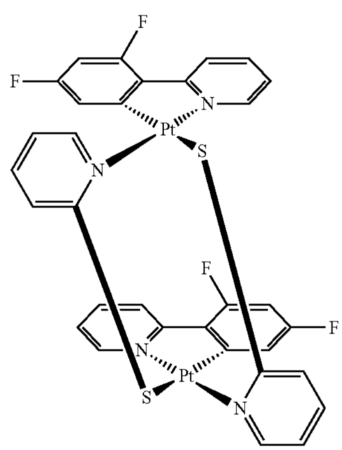
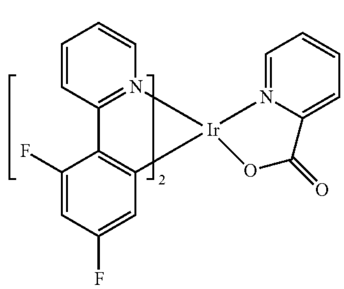
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Deuterated organometallic complexes		US20030138657
Organometallic complexes with two or more metal centers		US20030152802
		US7090928
	Blue dopants	
Iridium(III) organometallic complexes		WO2002002714

TABLE 4-continued

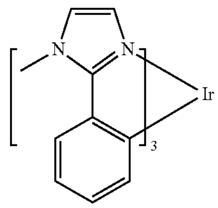
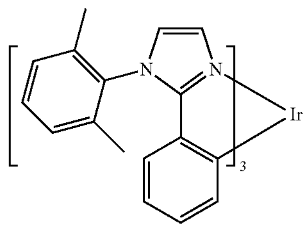
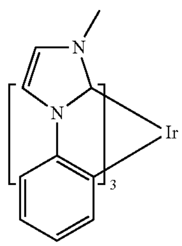
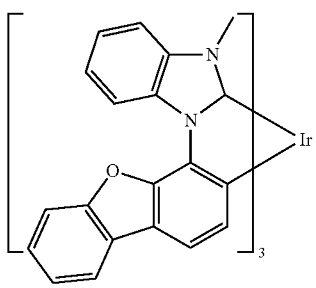
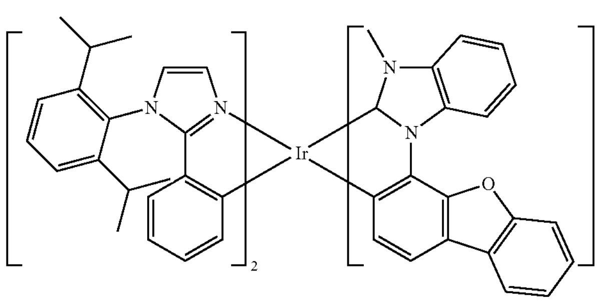
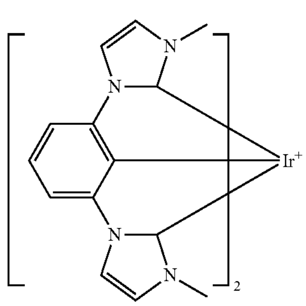
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2006009024
		US20060251923 US20110057559 US20110204333
		US7393599, WO2006056418, US20050260441, WO2005019373
		US7534505
		WO2011051404
		US7445855

TABLE 4-continued

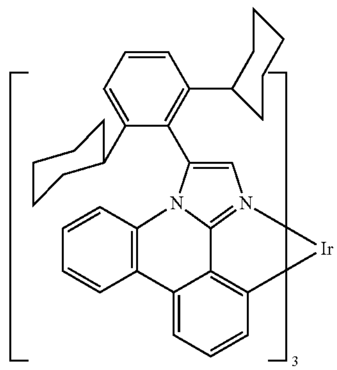
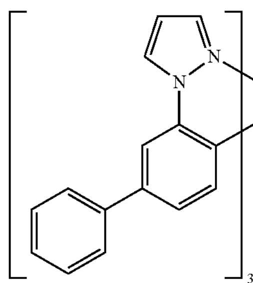
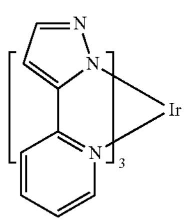
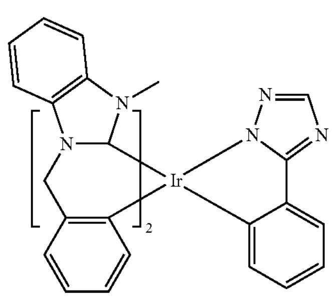
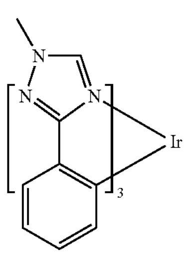
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070190359, US20080297033 US20100148663
		US7338722
		US20020134984
		Angew. Chem. Int. Ed. 47, 1 (2008)
		Chem. Mater. 18, 5119 (2006)

TABLE 4-continued

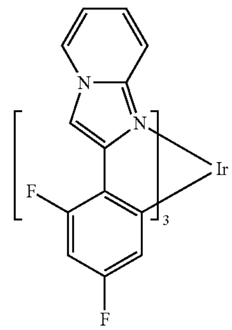
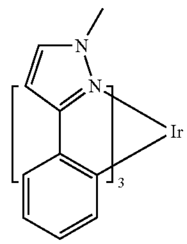
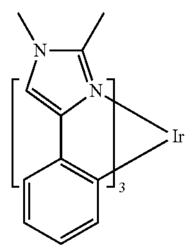
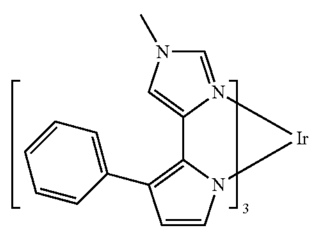
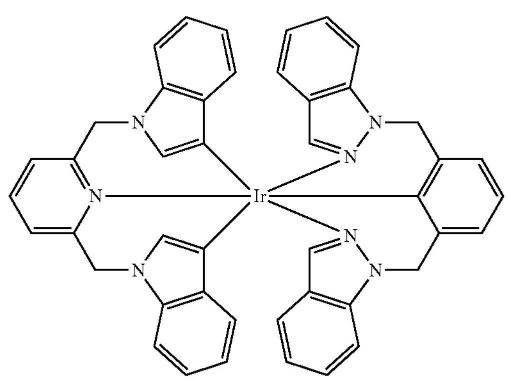
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Inorg. Chem. 46, 4308 (2007)
		WO2005123873
		WO2005123873
		WO2007004380
		WO2006082742

TABLE 4-continued

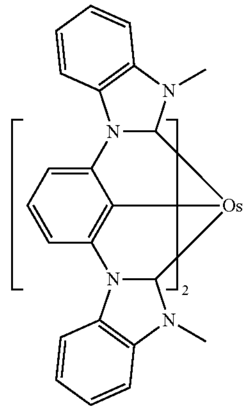
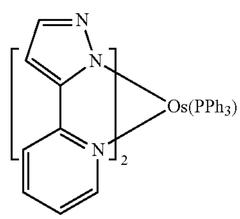
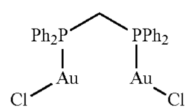
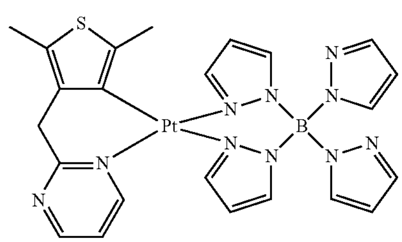
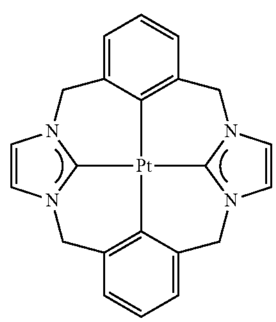
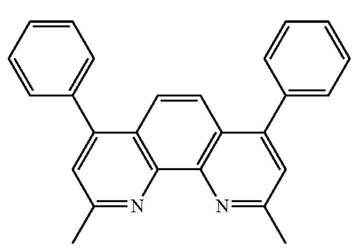
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium(II) complexes		US7279704
		Organometallics 23, 3745 (2004)
Gold complexes		Appl. Phys. Lett. 74, 1361 (1999)
Platinum(II) complexes		WO2006098120, WO2006103874
Pt tetradentate complexes with at least one metal-carbene bond		US7655323
	Exciton/hole blocking layer materials	
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)

TABLE 4-continued

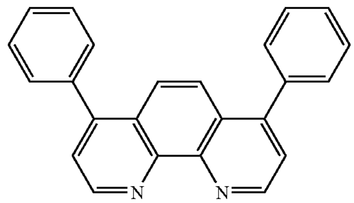
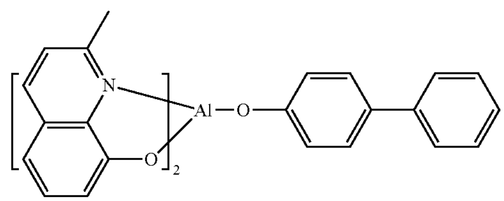
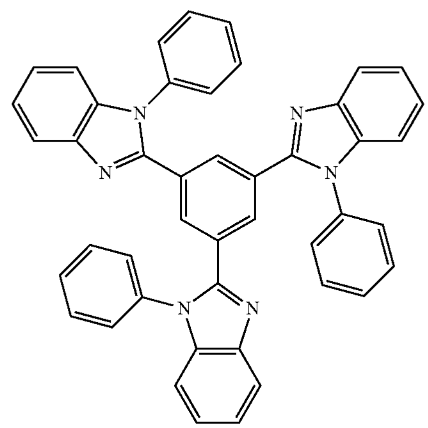
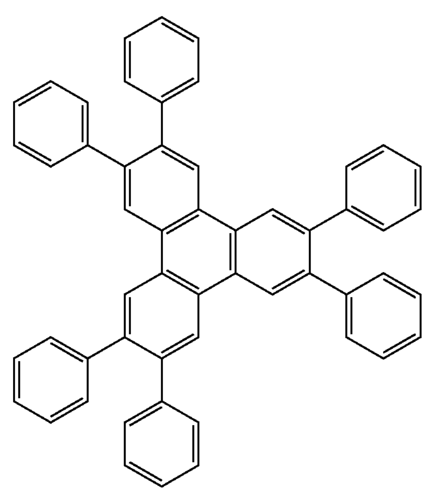
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 79, 449 (2001)
Metal 8-hydroxyquinolates (e.g., BAlq)		Appl. Phys. Lett. 81, 162 (2002)
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)
Triphenylene compounds		US20050025993

TABLE 4-continued

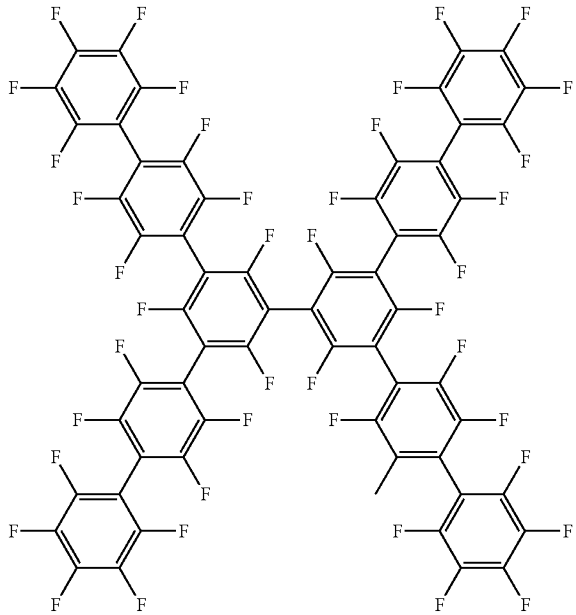
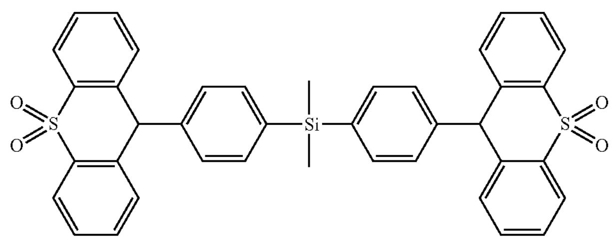
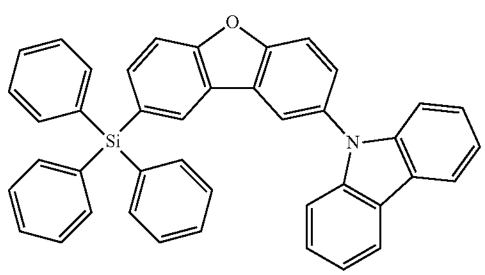
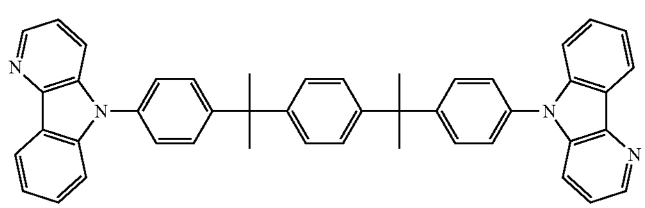
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)
Phenothiazine-S-oxide		WO2008132085
Silylated five-membered nitrogen, oxygen, sulfur or phosphorus dibenzoheterocycles		WO2010079051
Aza-carbazoles		US20060121308
	Electron transporting materials	

TABLE 4-continued

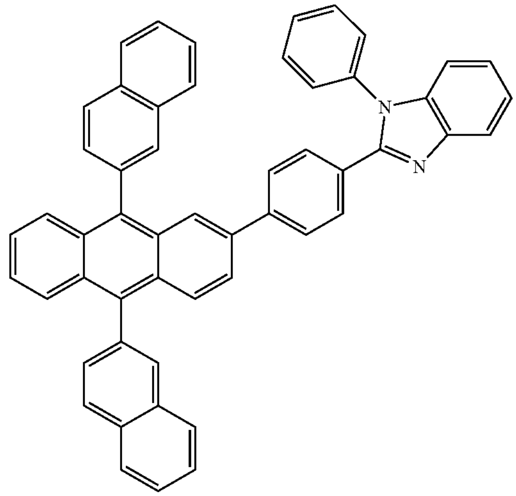
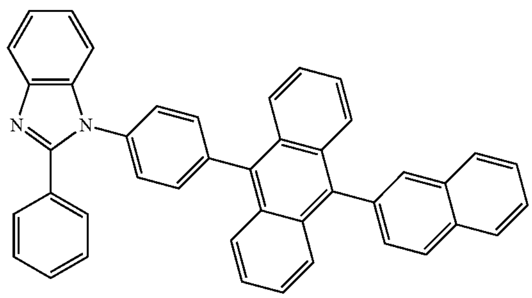
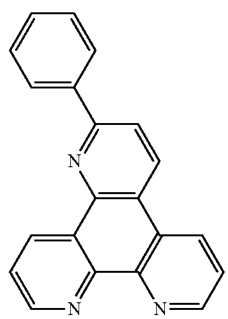
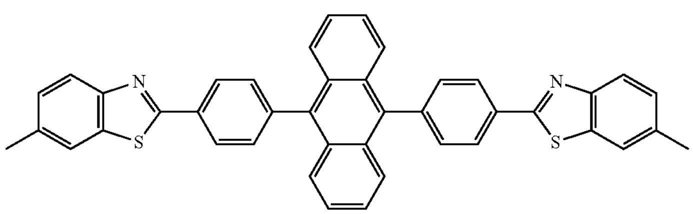
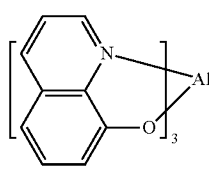
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Anthracene-benzoimidazole compounds		WO2003060956
		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)
Metal 8-hydroxyquinolates (e.g., Alq_3, Zrq_4)		Appl. Phys. Lett. 51, 913 (1987) US7230107

TABLE 4-continued

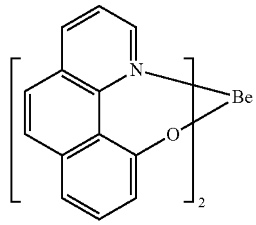
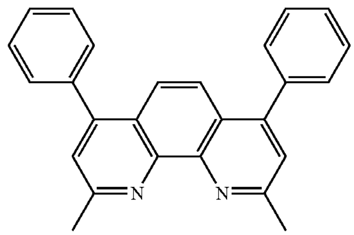
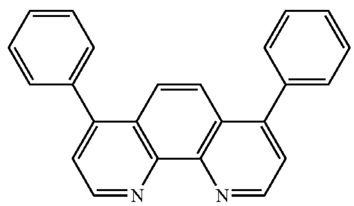
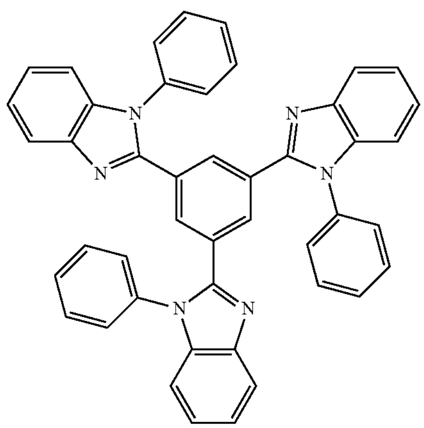
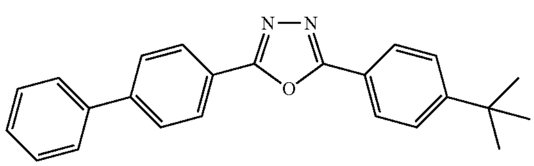
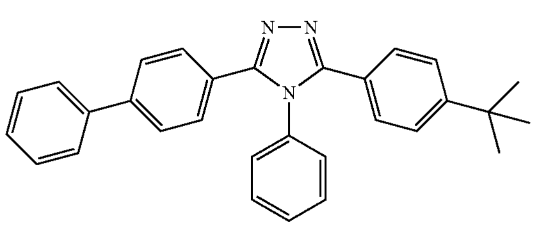
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal hydroxybenoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)
		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl. Phys. Lett. 74, 865 (1999)
		Appl. Phys. Lett. 55, 1489 (1989)
		Jpn. J. Apply. Phys. 32, L917 (1993)

TABLE 4-continued

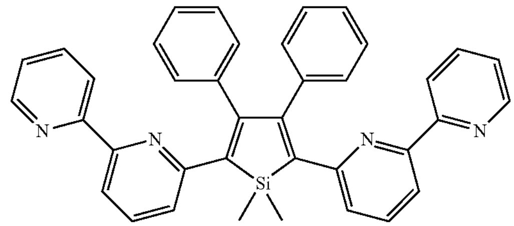
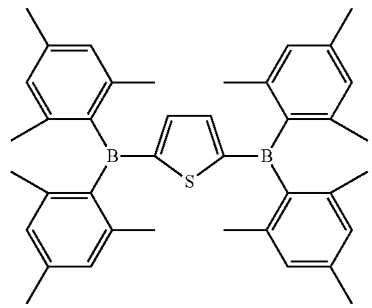
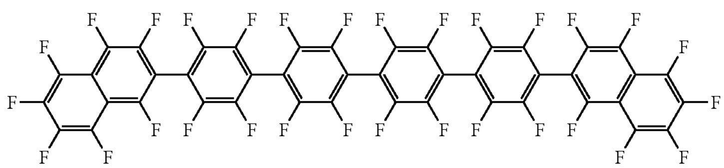
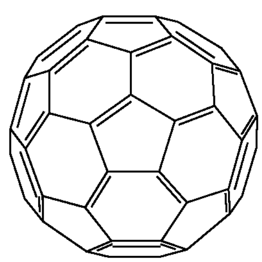
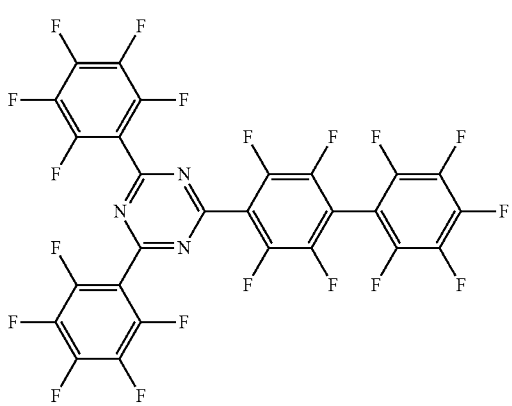
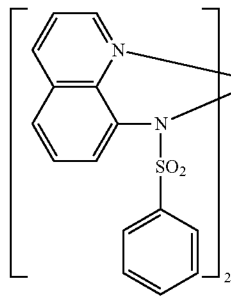
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silole compounds		Org. Electron. 4, 113 (2003)
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)
Fullerene (e.g., C60)		US20090101870
Triazine complexes		US20040036077

TABLE 4-continued

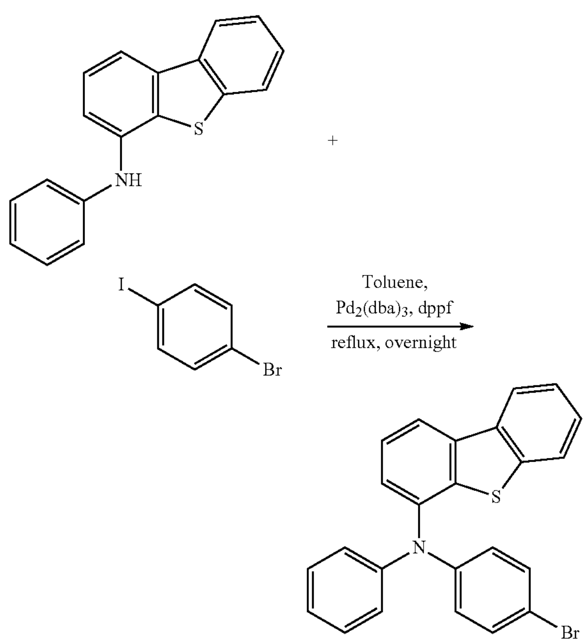
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Zn (N^N) complexes		US6528187

EXPERIMENTAL

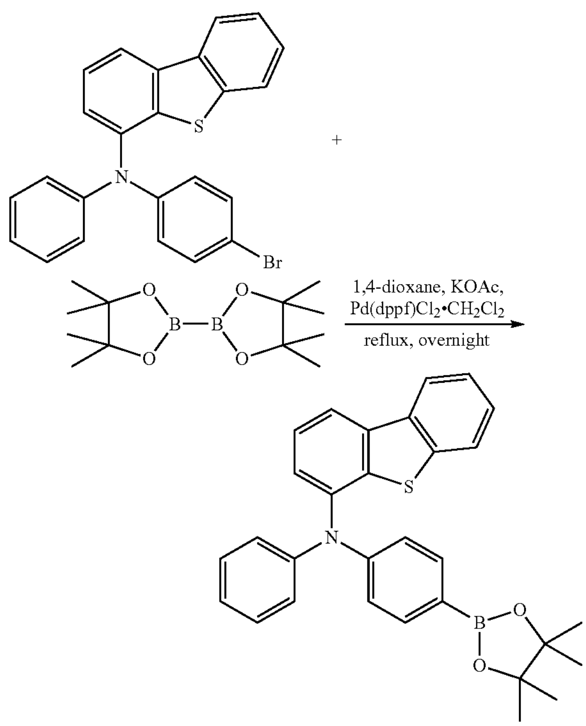
Chemical abbreviations used throughout this document are as follows: Cy is cyclohexyl, dba is dibenzylideneacetone, EtOAc is ethyl acetate, DME is dimethoxyethane, dppe is 1,2-bis(diphenylphosphino)ethane, THF is tetrahydrofuran, DMF is dimethylformamide, DCM is dichloromethane, S-Phos is dicyclohexyl(2',6'-dimethoxy-[1,1'-biphenyl]-2-yl)phosphine, Tf is trifluoromethylsulfonate. Unless specified otherwise, references to degassing a particular solvent refer to saturating the solvent sufficiently with dry nitrogen gas (by bubbling it in the solvent) to substantially remove gaseous oxygen from the solvent.

Synthesis of Compound 113

Synthesis of N-(4-bromophenyl)-N-phenyldibenzo[b,d]thiophen-4-amine



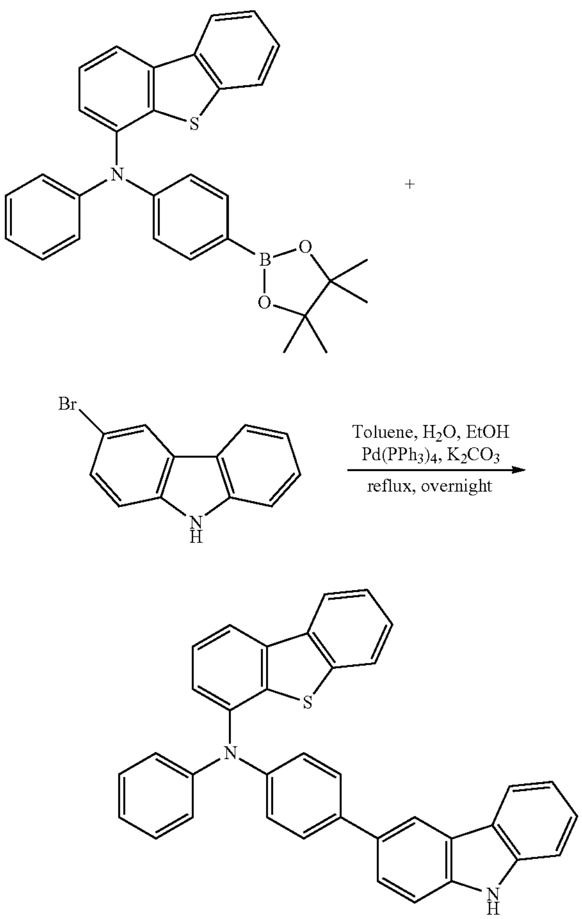
Toluene (125 mL) was bubbled with nitrogen gas for 15 minutes, and subsequently 1,1'-Bis(diphenylphosphino)ferrocene (0.2 g, 0.4 mmol) and $Pd_2(dba)_3$ (0.1 g, 0.1 mmol) were added. The mixture was bubbled with nitrogen gas for 15 minutes, then N-phenyldibenzo[b,d]thiophen-4-amine (3.2 g, 11.6 mmol), 1-bromo-4-iodobenzene (4.5 g, 15.9 mmol), NaO^tBu (1.5 g, 15.6 mmol) were added. The mixture was bubbled with nitrogen gas for 15 minutes and refluxed for 12 hours. After cooling, the reaction mixture was filtered through a silica pad and washed with 50% CH_2Cl_2/hexane. The solvent was removed in vacuo and the residue was purified by flash chromatography using 10-15% CH_2Cl_2/hexane to afford N-(4-bromophenyl)-N-phenyldibenzo[b,d]thiophen-4-amine (4.0 g, 80% yield) as a white solid.



Synthesis of N-phenyl-N-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]thiophen-4-amine

To a solution of N-(4-bromophenyl)-N-phenyldibenzo[b,d]thiophen-4-amine (8.3 g, 19.3 mmol) in 1,4-dioxane (250 mL) was added bis(pinacolato)diboron (7.6 g, 29.9 mmol), KOAc (3.9 g, 39.8 mmol), and the solution was bubbled with nitrogen for 15 minutes. $Pd(dppf)Cl_2.CH_2Cl_2$ (0.5 g, 0.6

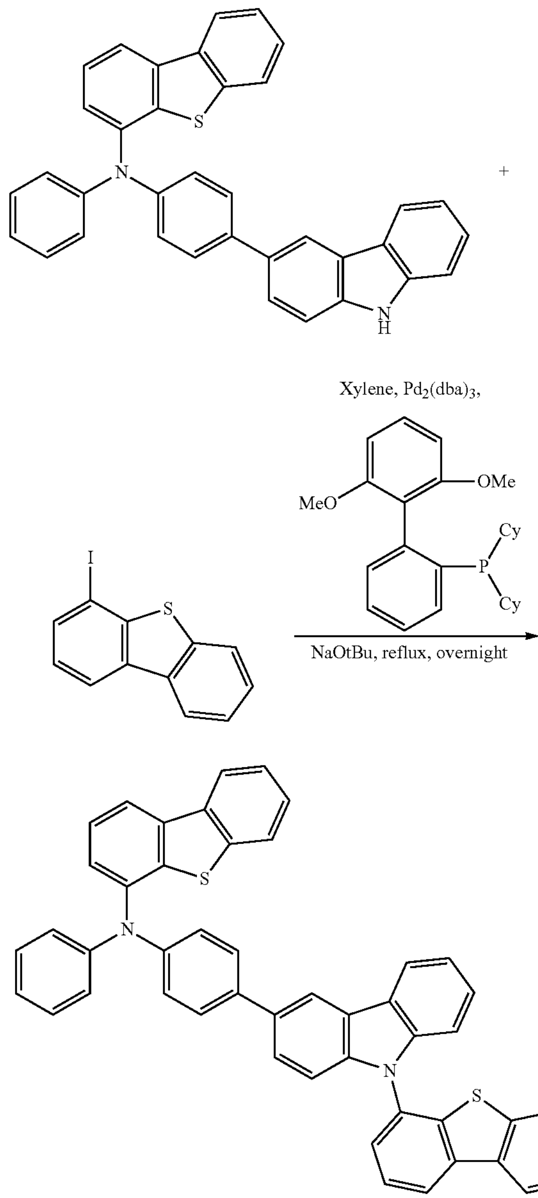
mmol) was then added to the solution, and the reaction mixture was bubbled with nitrogen for 15 minutes. The resultant mixture was refluxed for 12 hours. After cooling, H_2O (1 mL) was added and stirred for 15 min. The reaction mixture was filtered through a silica pad and washed with 75% CH_2Cl_2/hexane. The solvent was removed in vacuo and the residue was purified by flash chromatography using 25-40% CH_2Cl_2/hexane to afford N-phenyl-N-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]thiophen-4-amine (5.9 g, 64% yield) as a white solid.



Synthesis of N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]thiophen-4-amine

To a solution of N-phenyl-N-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]thiophen-4-amine (5.9 g, 12.4 mmol), 3-bromocabazole (3.5 g, 14.2 mmol), K_2CO_3 (16.6 g, 120.0 mmol) in toluene (150 mL), water (50 mL) and EtOH (50 mL) was bubbled for 30 min. $Pd(PPh_3)_4$ (0.4 g, 0.4 mmol) was added. The mixture was bubbled for 15 min. The resultant mixture was refluxed for 12 h. After cooling, the reaction mixture was extracted by CH_2Cl_2 and dried by $MgSO_4$. The solvent was removed in vacuo and the residue was purified by flash chromatography using 25-50% CH_2Cl_2/hexane to afford N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]thiophen-4-amine (5.8 g, 91% yield) as a white solid.

Synthesis of Compound 113

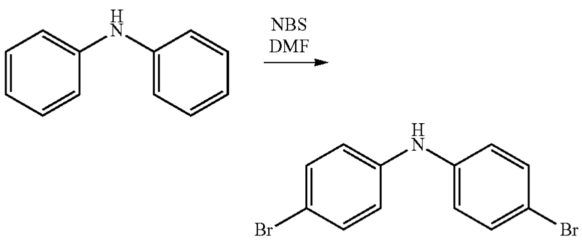


Compound 113

Xylene (175 mL) was bubbled with nitrogen for 15 minutes, followed by addition of 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (2.3 g, 5.6 mmol) and $Pd_2(dba)_3$ (1.3 g, 1.4 mmol). The mixture was again bubbled nitrogen for 15 minutes, then N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]thiophen-4-amine (3.4 g, 6.6 mmol), 4-iododibenzothiophene (3.3 g, 10.6 mmol), sodium tert-butoxide (1.4 g, 14.0 mmol) were added. The mixture was bubbled with nitrogen for 15 minutes and refluxed for 12 hours. After cooling, the reaction mixture was filtered through a silica pad and washed with 80% CH_2Cl_2/hexane. The solvent was removed in vacuo and the residue was purified by flash chromatography using 20-35% CH_2Cl_2/hexane to afford Compound 113 (2.9 g, 63% yield) as a white solid.

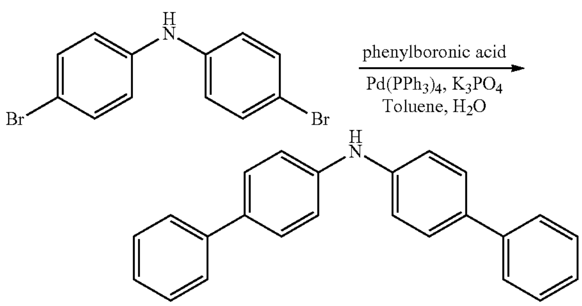
Synthesis of Compound 178

Synthesis of bis(4-bromophenyl)amine



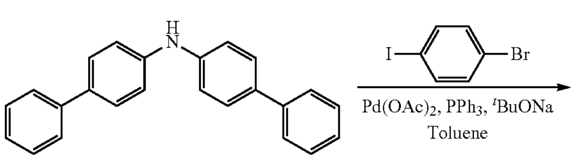
N-bromosuccinimide (17.8 g, 0.1 mol) in 50 mL of DMF was added slowly to diphenylamine (8.46 g, 0.05 mol) in 50 mL of DMF at 0° C. in 30 minutes. The reaction was allowed to warm to room temperature and stir overnight. The white precipitate was filtered and air dried, and 16 g of product was collected.

Synthesis of di([1,1'-biphenyl]-4-yl)amine



Bis(4-bromophenyl)amine (4.0 g, 12.3 mmol) and phenylboronic acid (4.0 g, 32.7 mmol) were mixed in 250 mL of toluene and 60 mL of ethanol. The solution was bubbled with nitrogen while stirring for 15 minutes. $Pd(PPh_3)_4$ (1.4 g, 1.23 mmol) and K_3PO_4 (13.5 g, 64 mmol) were added in sequence. The mixture was heated to reflux overnight under nitrogen. After cooling, the reaction mixture was filtered through filter paper and the solvent was then evaporated. The solid was redissolved in nitrogen-purged hot toluene and was filtered through a Celite®/silica pad when the solution was still hot. The solvent was then evaporated. The white crystalline solid was washed by hexane and air dried to obtain 3.8 g of product.

Synthesis of N-([1',1'-biphenyl]-4-yl)-N-(4-bromophenyl)-[1,1'-biphenyl]-4-amine



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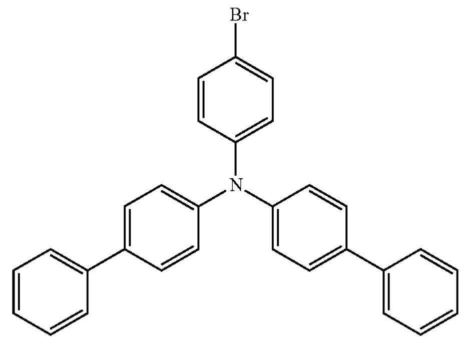
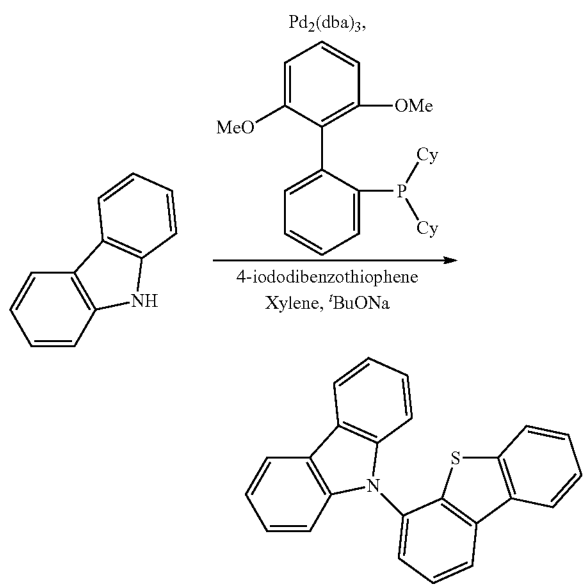


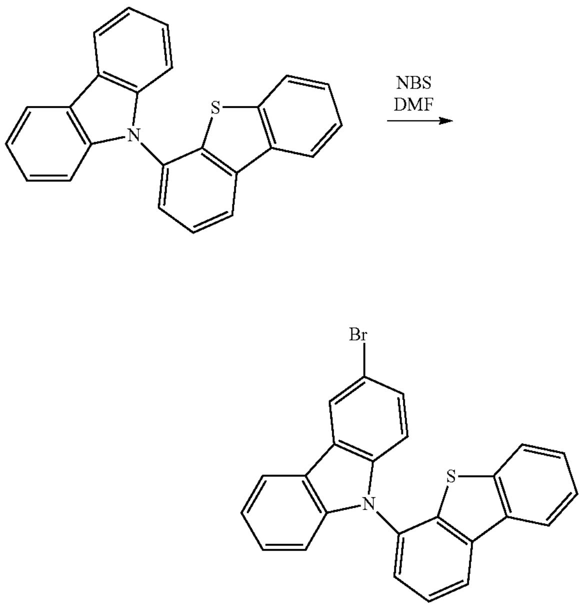
Di([1,1'-biphenyl]-4-yl)amine (3.5 g, 10.9 mmol) and 1-bromo-4-iodobenzene (6.0 g, 21.3 mmol) were mixed in 300 mL of dry toluene. The solution was bubbled with nitrogen while stirring for 15 minutes. $Pd(OAc)_2$ (36 mg, 0.16 mmol), triphenylphosphine (0.16 g, 0.6 mmol) and sodium t-butoxide (2.0 g, 20.8 mmol) were added in sequence. The mixture was heated to reflux overnight under nitrogen. After cooling, the reaction mixture was filtered through Celite®/silica pad and the solvent was then evaporated. The residue was then purified by column chromatography using DCM: hexane (1:4, v/v) as the eluent to obtain 3.9 g of product.

Synthesis of 9-(dibenzo[b,d]thiophen-4-yl)-9H-carbazole



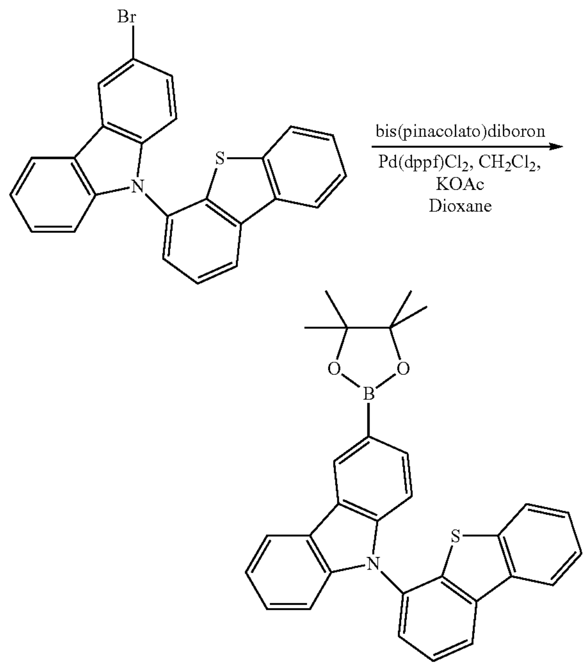
Carbazole (0.62 g, 3.67 mmol) and 4-iododibenzothiophene (1.2 g, 3.87 mmol) were mixed in 70 mL of dry xylene. The solution was bubbled nitrogen while stirring for 15 minutes. $Pdz(dba)_3$ (0.16 g, 0.17 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.24 g, 0.58 mmol) and sodium tert-butoxide (1.0 g, 10.4 mmol) were added in sequence. The mixture was heated to reflux for 3 days under nitrogen. After cooling, the reaction mixture was filtered through a Celite®/silica pad and the solvent was then evaporated. The residue was then purified by column chromatography using DCM:hexane (1:4, v/v) as the eluent to obtain 0.64 g of product.

Synthesis of 3-bromo-9-(dibenzo[b,d]thiophen-4-yl)-9H-carbazole



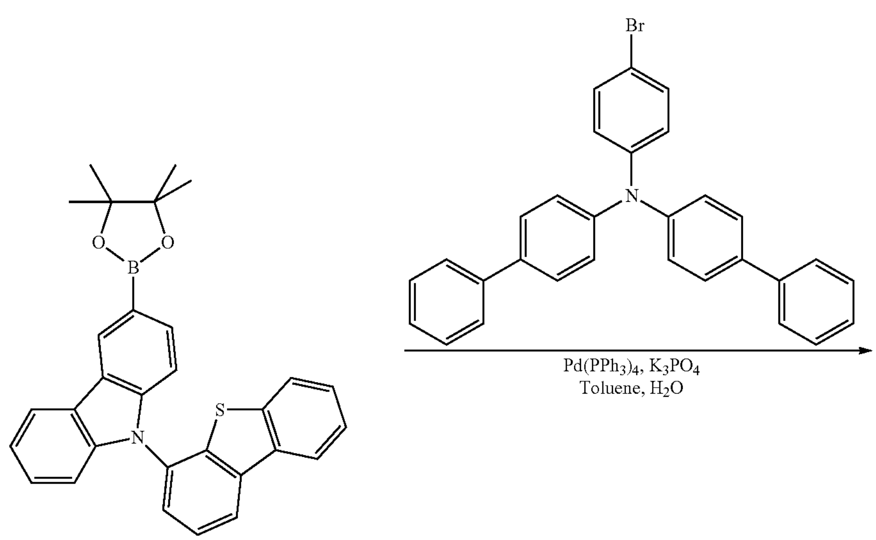
N-bromosuccinimide (0.31 g, 1.74 mmol) in 5 mL DMF was added slowly to 9-(dibenzo[b,d]thiophen-4-yl)-9H-carbazole (0.6 g, 1.72 mmol) in 50 mL of DCM at 0° C. The reaction was allowed to warm to room temp and stirred overnight. The reaction mixture was extracted with DCM and dried over $MgSO_4$ and the solvent was evaporated. The residue was purified by column chromatography using DCM: hexane (1:4, v/v) as the eluent to obtain 0.45 g of product.

Synthesis of 9-(dibenzo thiophen-4-yl)-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9H-carbazole



3-bromo-9-(dibenzo[b,d]thiophen-4-yl)-9H-carbazole (0.45 g, 1.1 mmol), bis(pinacolato)diboron (0.43 g, 1.4 mmol) and KOAc (0.31 g, 3.1 mmol) were mixed in 150 mL of dry 1,4-dioxane. The solution was bubbled with nitrogen while stirring for 15 minutes, then $Pd(dppf)Cl_2.CH_2Cl_2$ (26 mg, 0.03 mmol) was added. The mixture was heated to reflux overnight under nitrogen. After cooling, the reaction mixture was filtered through Celite®/silica pad and the solvent was then evaporated. The residue was then purified by column chromatography using DCM:hexane (3:7, v/v) as the eluent to obtain 0.4 g of product.

Synthesis of Compound 178



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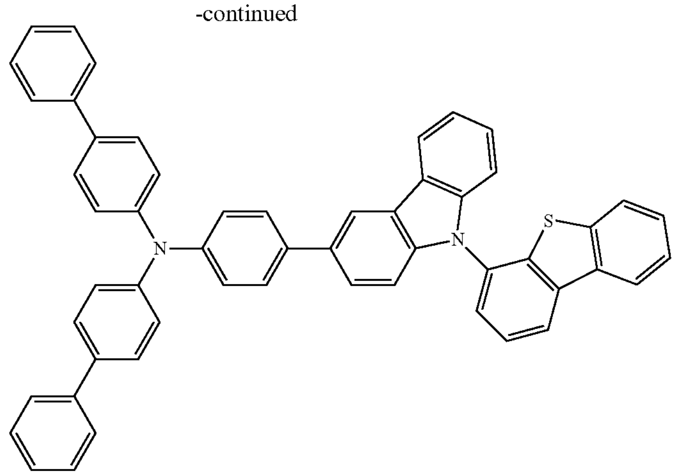
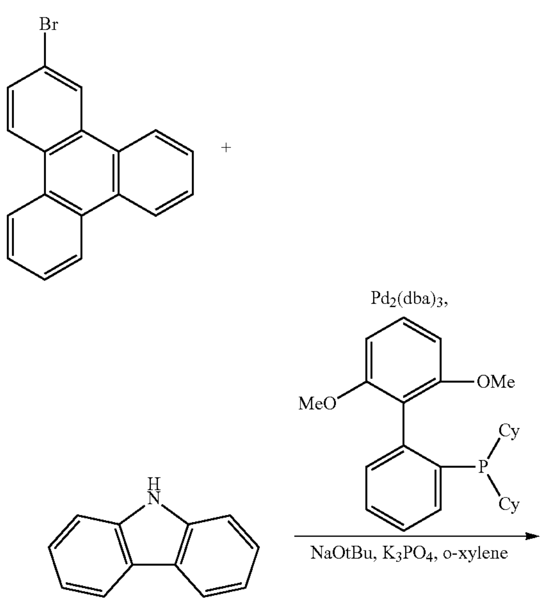


N-([1,1'-biphenyl]-4-yl)-N-(4-bromophenyl)-[1,1'-biphenyl]-4-amine (2.5 g, 5.25 mmol), and 9-(dibenzo[b,d]thiophen-4-yl)-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9H-carbazole (2.64 g, 5.58 mmol) were mixed in 250 mL of toluene and 30 mL of deionized water. The solution was bubbled with nitrogen while stirring for 15 minutes, then $Pd_2(dba)_3$ (0.12 g, 0.13 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.21 g, 0.51 mmol) and K_3PO_4 (3.5 g, 16.5 mmol) were added in sequence. The mixture was heated to reflux overnight under nitrogen. Bromobenzene (1 mL) was added to the reaction mixture and the reaction was further refluxed for 4 hours. After cooling, the reaction mixture was filtered through a Celite®/silica pad and the solvent was then evaporated. Compound 178 (2.4 g) was collected and purified by recrystallization from 20 mL of degassed toluene.

Compound 182

Synthesis of 9-(triphenylen-2-yl)-9H-carbazole



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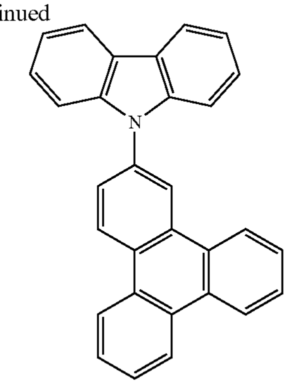
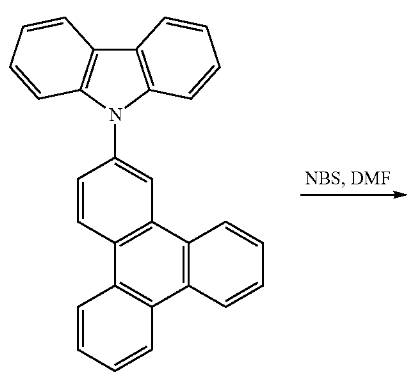


To a stirred solution of $Pd_2(dba)_3$ (0.52 g, 0.57 mmol) in o-xylene (140 mL), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.94 g, 2.3 mmol) was added and degassed with nitrogen for 15 minutes. Carbazole (5.33 g, 31.9 mmol) and 2-bromotriphenylene (7.0 g, 22.7 mmol), sodium tert-butoxide (6.57 g, 68.3 mmol) were added and degassed with nitrogen for another 15 minutes. The reaction was refluxed for 2 days. The reaction mixture was filtered through silica, washed with DCM and dried under vacuum. Silica gel chromatography with 10% DCM/hexane, yielded 4.98 g of a while solid (56%) as the product.

Synthesis of 3-bromo-9-(triphenylen-2-yl)-9H-carbazole



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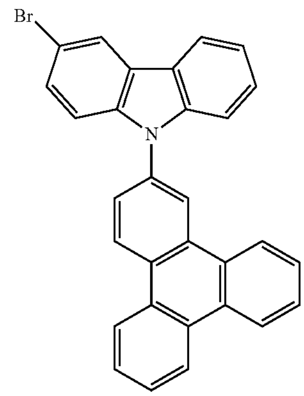
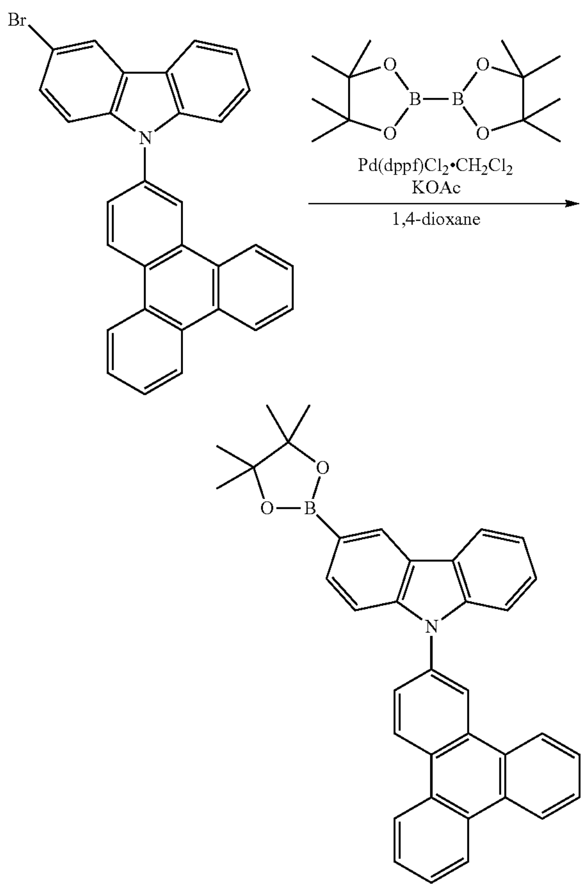


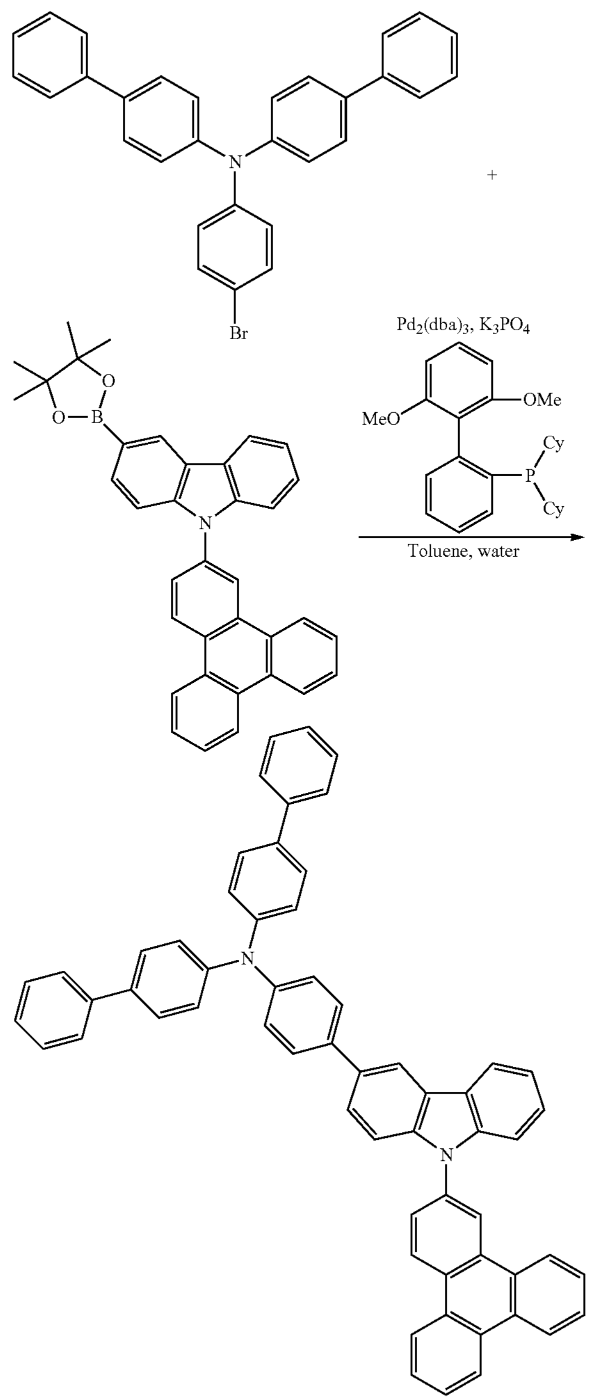
To a stirred solution of 9-(triphenylen-2-yl)-9H-carbazole (4.7 g, 11.9 mmol) in DMF (24 mL) at 0° C. under N_2, NBS (N-bromosuccinimide) (2.1 g, 11.9 mmol) in DMF (24 mL) was added dropwise. After the completion of addition, the reaction mixture was warmed to room temperature overnight with vigorous stirring. The reaction mixture was precipitated with water and the solid was filtered. The pale grey solid was re-dissolved in a small amount of THF, added on a silica plug and flushed with 30% DCM/hexane. The filtrate was dried under vacuum and the white solid was used without further purification (5.5 g, 98 N.

Synthesis of 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9-(triphenylen-2-yl)-9H-carbazole



To a stirred solution of 3-bromo-9-(triphenylen-2-yl)-9H-carbazole (3.0 g, 6.4 mmol) in 1,4-dioxane (90 mL), bis(pinacolato)diboron (2.4 g, 9.5 mmol) and KOAc (1.8 g, 19.1 mmol) were added and degassed with nitrogen for 15 min, then Pd(dppf)Cl_2.CH_2Cl_2 (0.14 g, 0.2 mmol) was added and the mixture was degassed with nitrogen for another 15 minutes. The solution was refluxed for 2 days. After cooling to room temperature, water (1 mL) was added and the reaction mixture was stirred for 30 minutes. The reaction mixture was filtered through silica and dried under vacuum. The solid was column chromatographed with 20-50% DCM/hexane, yielding 2.0 g of a while solid (61%) as the product.

Synthesis of Compound 182



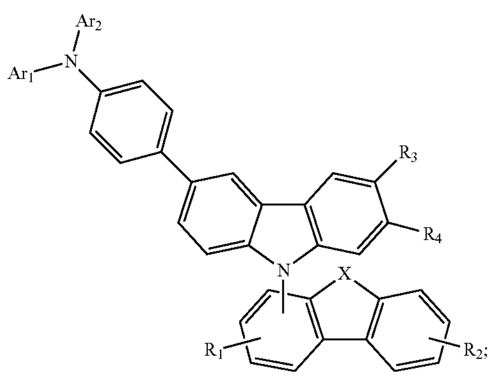
To a stirred solution of N-([1,1'-biphenyl]-4-yl)-N-(4-bromophenyl)-[1,1'-biphenyl]-4-amine (0.9 g, 1.9 mmol) in toluene (29 mL) and water (2.9 mL), 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9-(triphenylen-2-yl)-9H-carbazole (1.0 g, 1.9 mmol) and K_3PO_4 (2.4 g, 11.3 mmol) were added and the mixture was degassed with nitrogen for 15 minutes, then $Pd_2(dba)_3$ (86 mg, 0.09 mmol) and 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.16 g, 0.38 mmol) were added and degassed with nitrogen for another 15 minutes. The mixture was refluxed overnight. After cooling to room temperature, the reaction mixture was filtered through silica, washed with DCM and dried under vacuum. It was column chromatographed with 20-50% DCM/hexane yielding 1.03 g of a while solid (69%) as Compound 182.

It is understood that the various embodiments described herein are by way of example only, and are not intended to limit the scope of the invention. For example, many of the materials and structures described herein may be substituted with other materials and structures without deviating from the spirit of the invention. The present invention as claimed may therefore include variations from the particular examples and preferred embodiments described herein, as will be apparent to one of skill in the art. It is understood that various theories as to why the invention works are not intended to be limiting.

The invention claimed is:

1. A compound having the formula:

Formula I



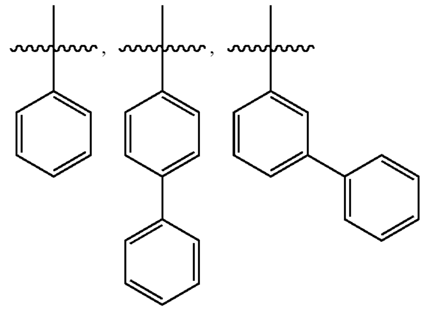
wherein Ar_1 and Ar_2 are independently selected from the group consisting of aryl and heteroaryl; and

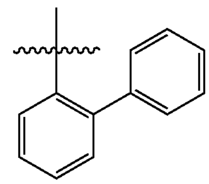
wherein X is selected from the group consisting of O, S, and Se;

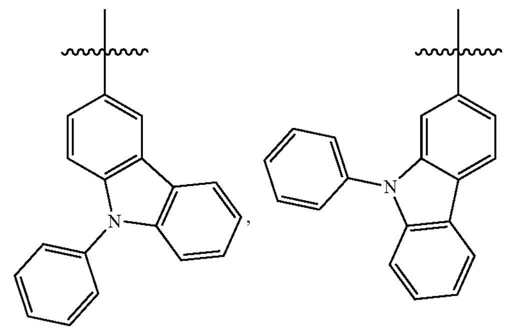
wherein R_1 and R_2 independently represent mono, di, tri, tetra substitution, or no substitution; and

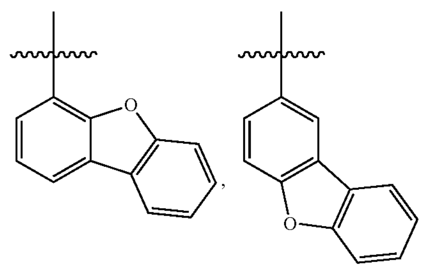
wherein R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

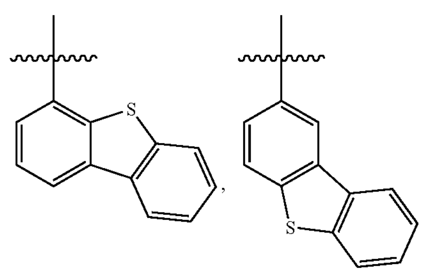
wherein Ar1 and Ar2 are independently selected from the groups consisting of:

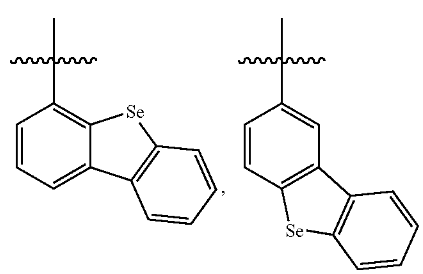












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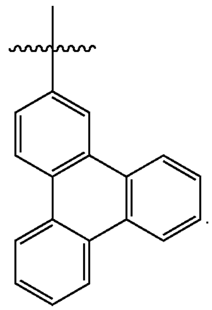
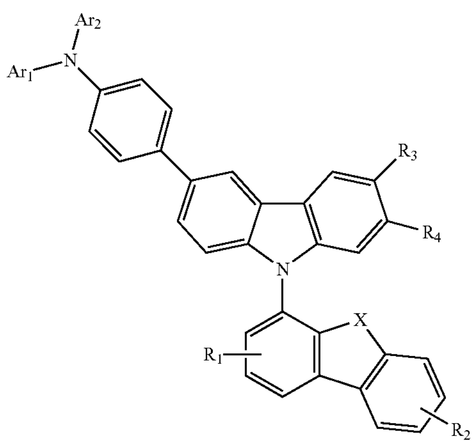


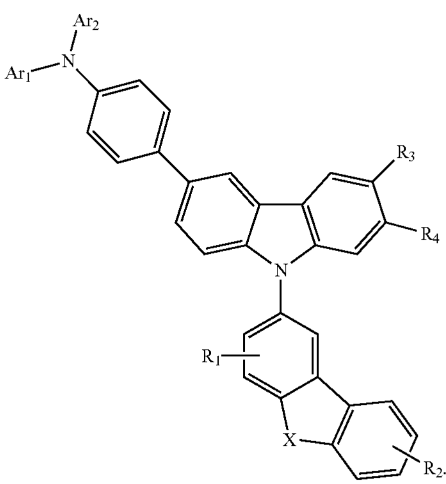
2. The compound of claim 1, wherein R_3 and R_4 are independently selected from the group consisting of alkyl, heteroalkyl, arylalkyl, aryl, and heteroaryl.

3. The compound of claim 1, wherein R_3 and R_4 are hydrogen or deuterium.

4. The compound of claim 1, wherein the compound has the formula:



or

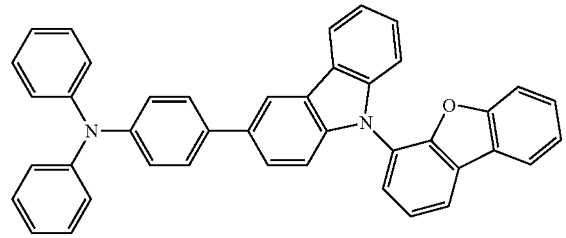


5. The compound of claim 1, wherein X is O or S.

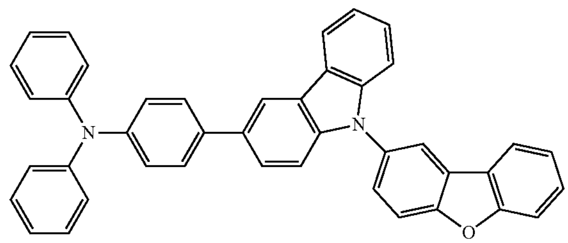
6. The compound of claim 1, wherein Ar_1 and Ar_2 are aryl.

7. The compound of claim 1, wherein the compound is selected from the group consisting of:

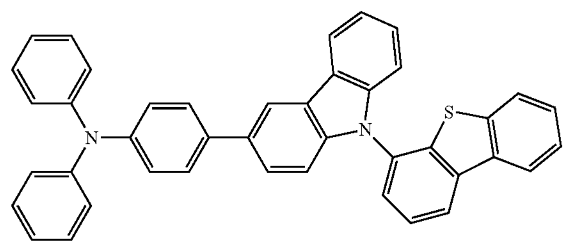
Compound 7



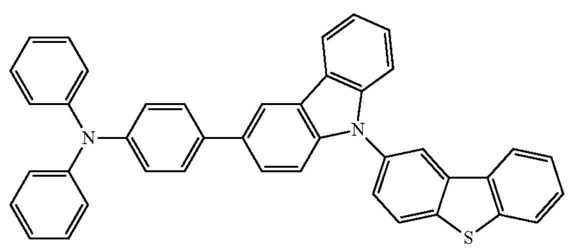
Compound 8



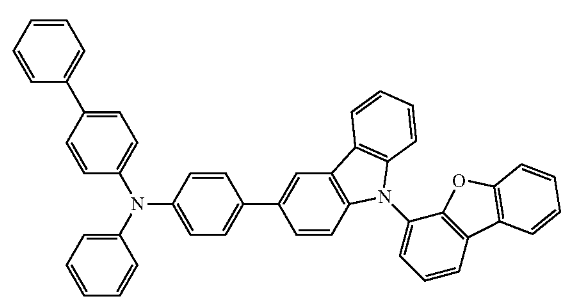
Compound 9



Compound 10



Compound 20



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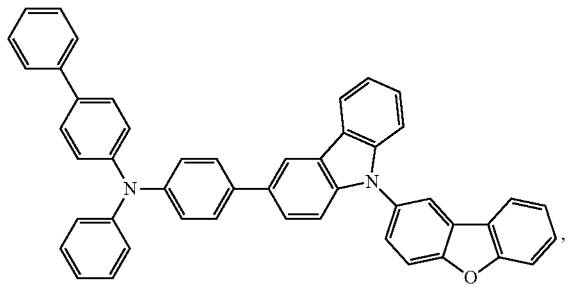
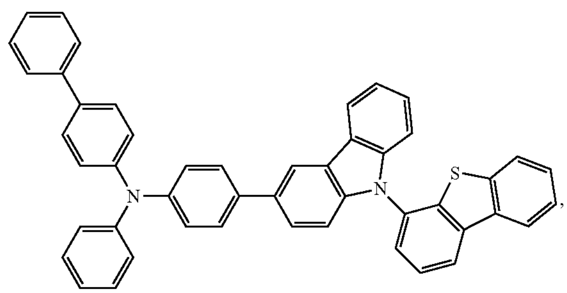
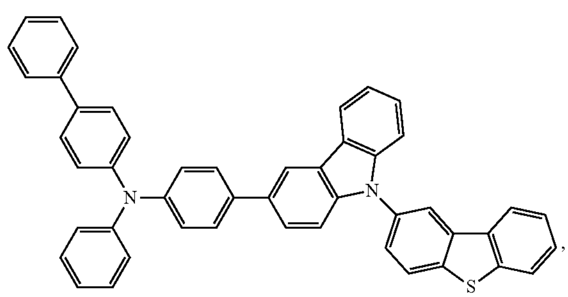
Compound 21



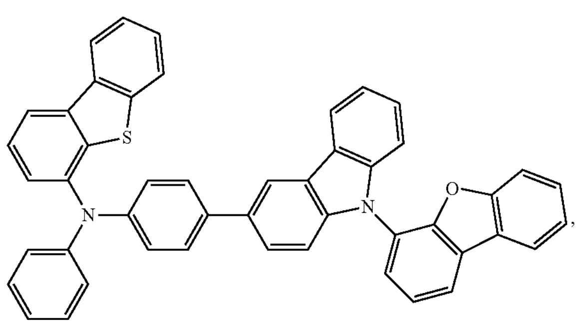
Compound 22



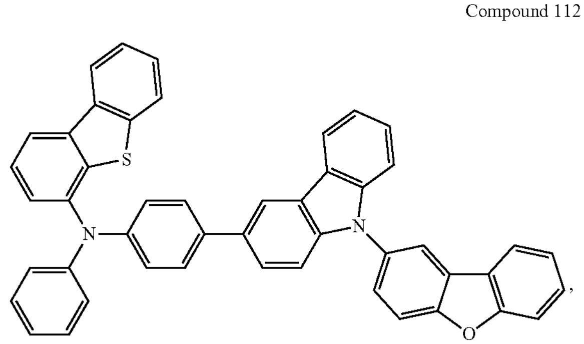
Compound 23



Compound 111



Compound 112



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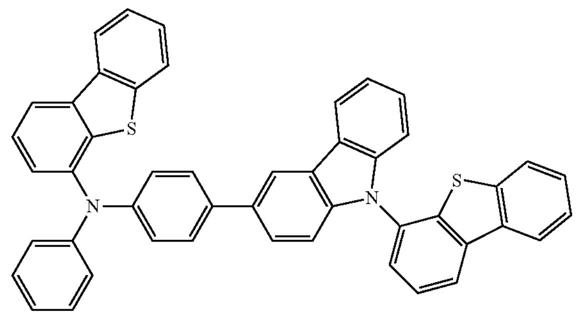
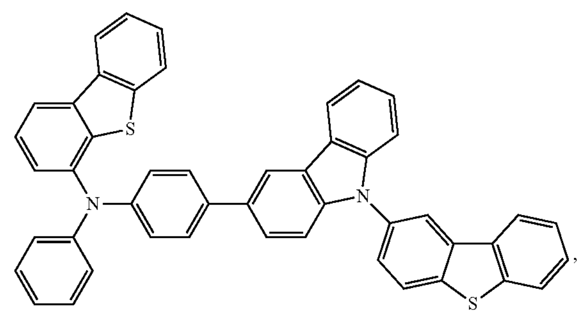
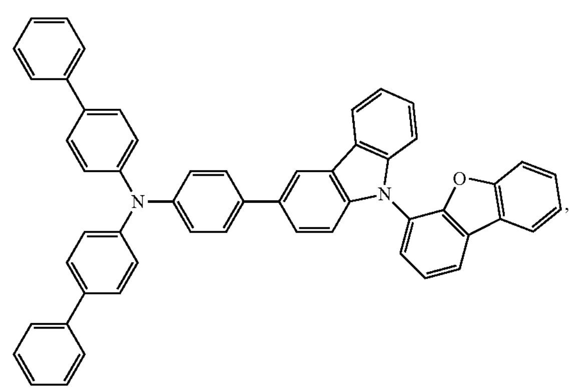
Compound 113



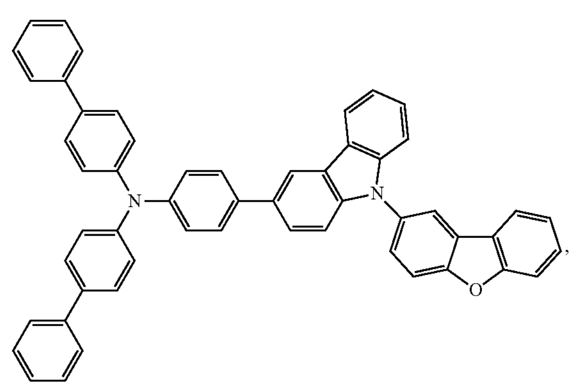
Compound 114



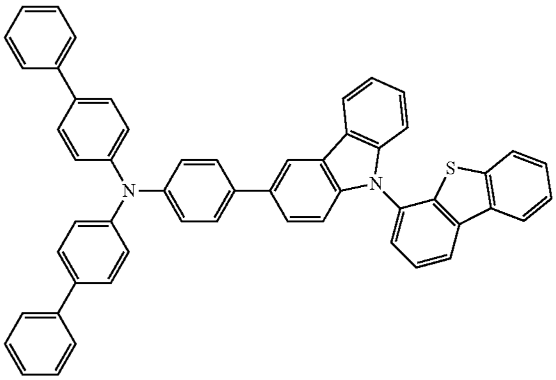
Compound 176



Compound 177

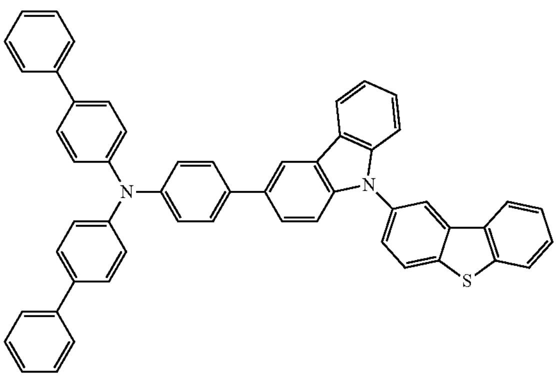


Compound 178



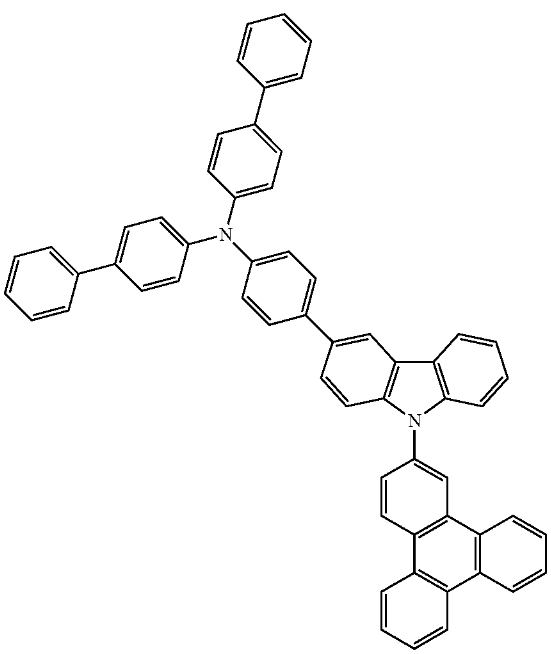
,

Compound 179



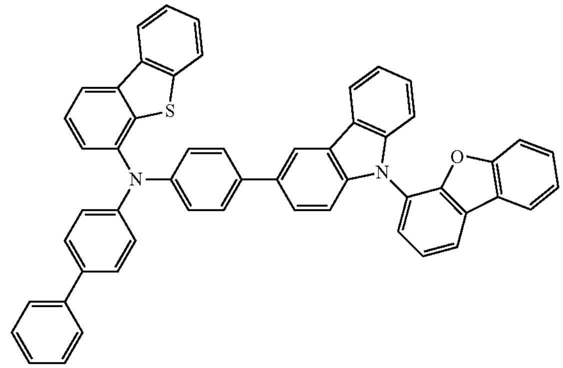
,

Compound 182



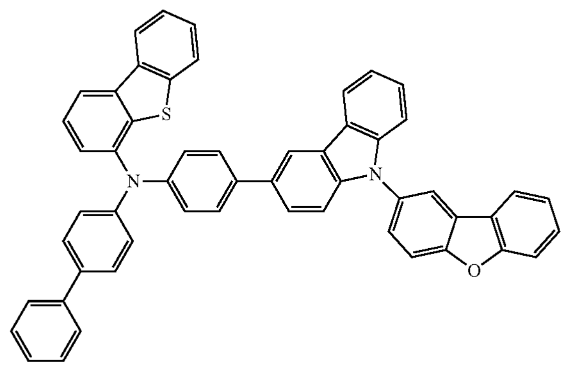
,

Compound 267



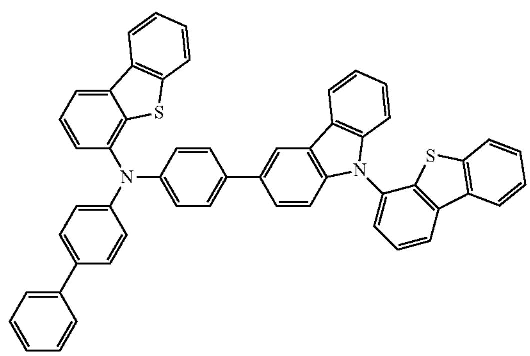
,

Compound 268



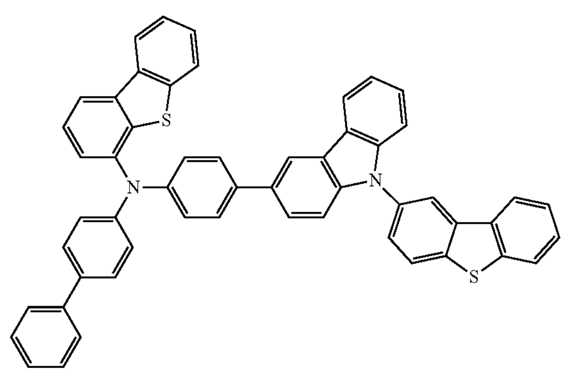
,

Compound 269



, and

Compound 270



.

8. A first device comprising an organic light emitting device, further comprising:

an anode;

a cathode; an emissive layer disposed between the anode and the cathode;

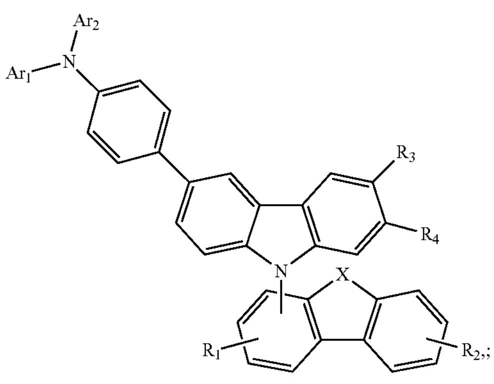
a hole injection layer disposed between the anode and the emissive layer;

a first hole transport layer disposed between the hole injection layer and the emissive layer; and

a second hole transport layer disposed between the first hole transport layer and the emissive layer; and

wherein the second hole transport layer comprises a compound of formula:

Formula I

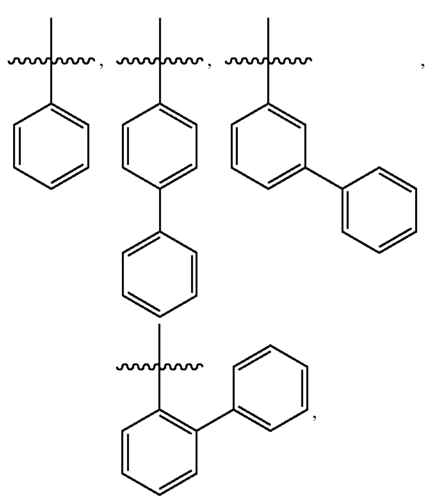


wherein X is selected from the group consisting of O, S, and Se;

wherein R_1 and R independently represent mono, di, tri, tetra substitution, or no substitution; and

wherein R_1, R_2, R_3, and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkenyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

wherein Ar_1 and Ar_2 are independently selected from the groups consisting of:



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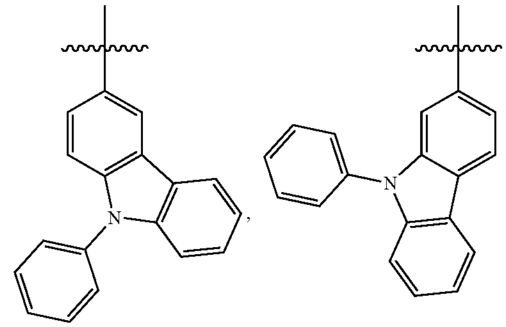
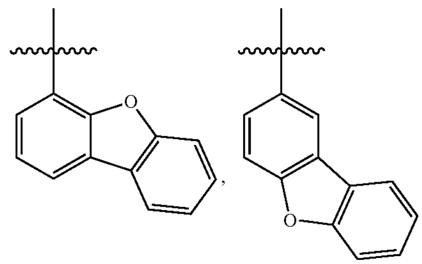
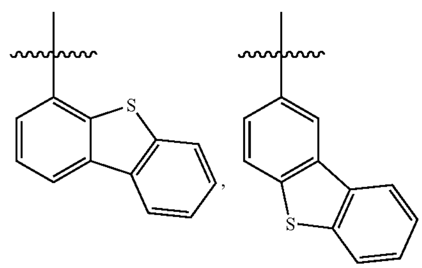
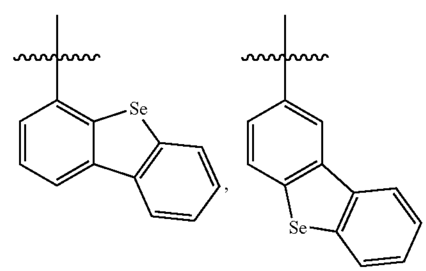
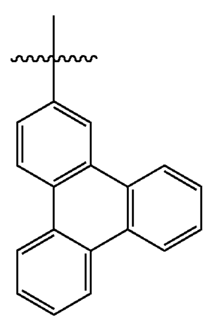








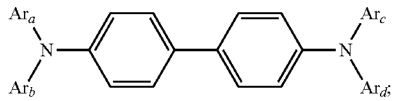
and



9. The first device of claim 8, wherein the second hole transport layer is disposed adjacent to the first hole transport layer.

10. The first device of claim 8, wherein the first hole transport layer is thicker than the second hole transport layer.

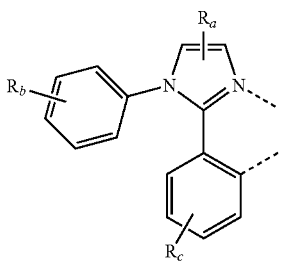
11. The first device of claim 8, wherein the first hole transport layer comprises a compound with the formula:

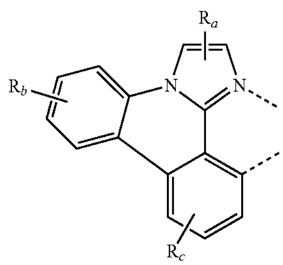


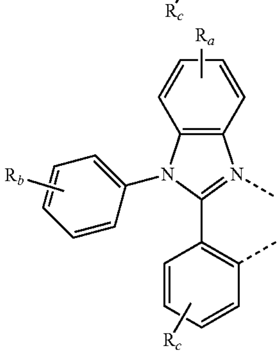
wherein Ar_a, Ar_b, Ar_c and Ar_d are independently selected from the group consisting of aryl and heteroaryl.

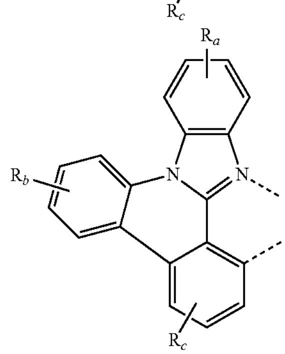
12. The first device of claim **8**, wherein the triplet energy of the compound of Formula II is higher than the emission energy of the emissive layer.

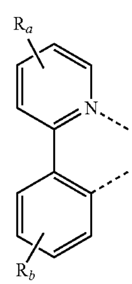
13. The first device of claim **8**, further comprising a first dopant material that is an emissive dopant comprising a transition metal complex having at least one ligand or part of the ligand if the ligand is more than bidentate selected from the group consisting of:

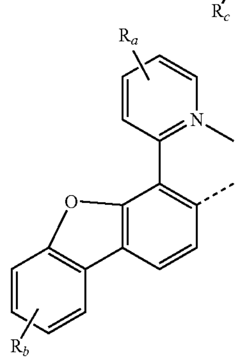


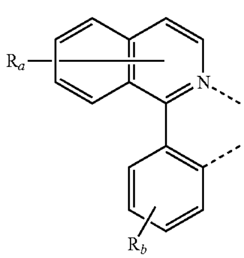


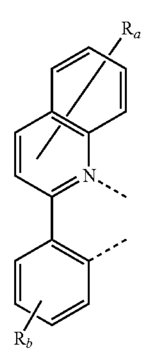












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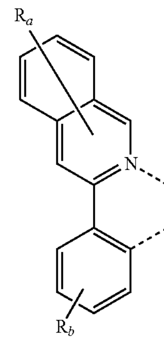

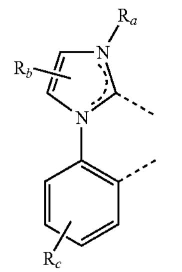

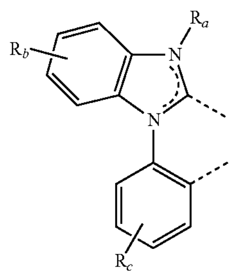

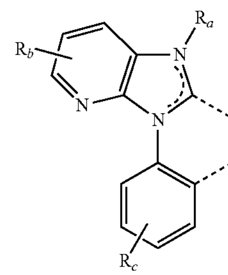

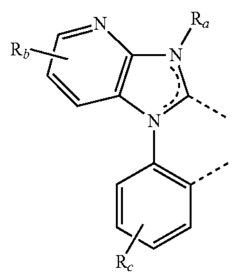

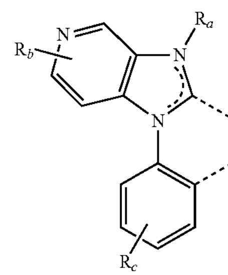

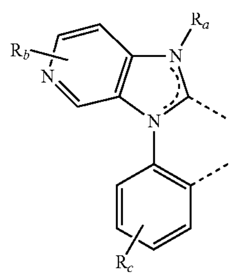

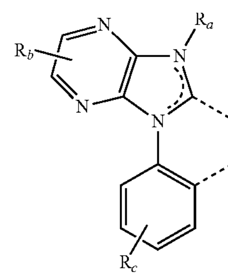

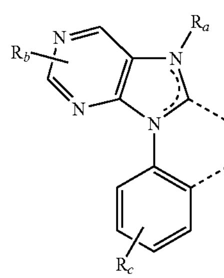

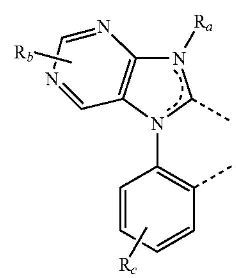

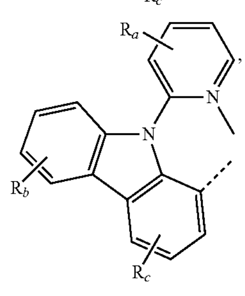

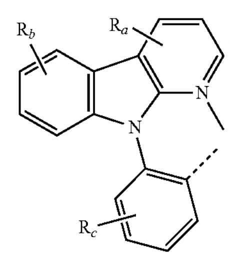

and

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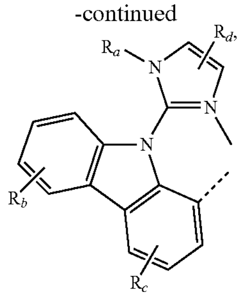


wherein R_a, R_b, R_c, and R_d may represent mono, di, tri, or tetra substitution, or no substitution;

wherein R_a, R_b, R_c, and R_d are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

wherein two adjacent substituents of R_a, R_b, R_c, and R_d are optionally joined to form a fused ring or form a multidentate ligand.

14. The first device of claim **8**, wherein the first device is a consumer product.

15. The first device of claim **8**, wherein the first device is an organic light-emitting device.

16. The first device of claim **8**, wherein the first device comprises a lighting panel.

17. A first device comprising an organic light emitting device, further comprising:

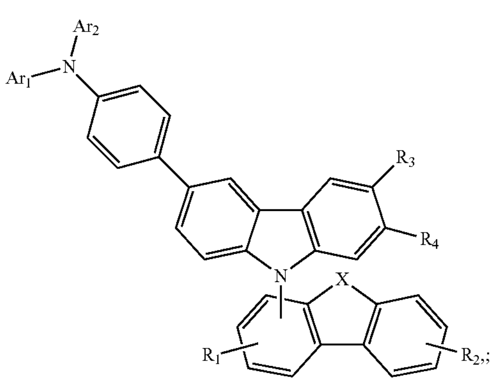
an anode;

a cathode;

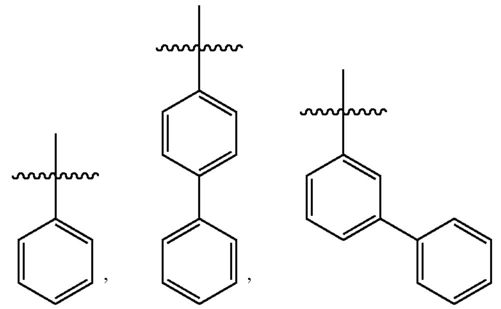
a first organic layer disposed between the anode and the cathode; and

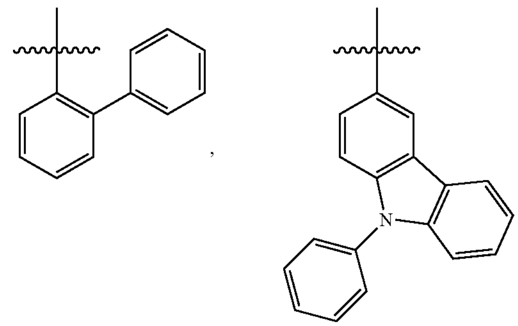
wherein the first organic layer comprises a compound of formula:

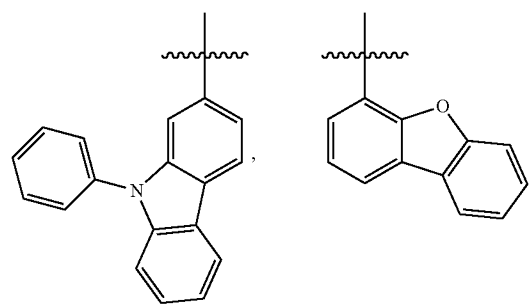
Formula I

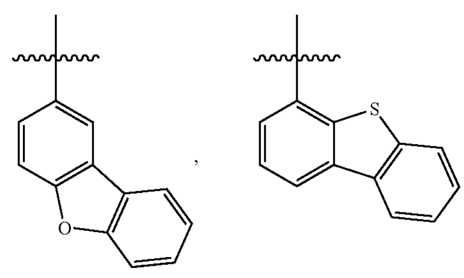


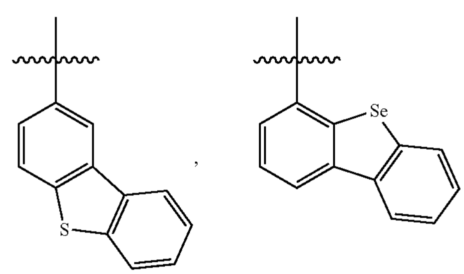
wherein Ar_1 and Ar_2 are independently selected from the groups consisting of:











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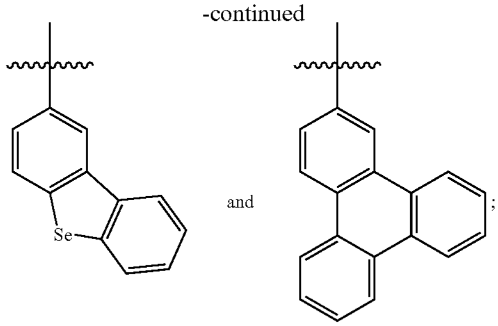

wherein X is selected from the group consisting of O, S, and Se;

wherein R1 and R2 independently represent mono, di, tri, tetra substitution, or no substitution; and

wherein R_1, R_2, R_3 and R_4 are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

18. The first device of claim **17**, wherein the first organic layer is an emissive layer.

19. The first device of claim **18**, wherein the emissive layer is a phosphorescent emissive layer.

* * * * *